KEITHLEY

INSTRUCTION MANUAL

MODEL 245

HIGH VOLTAGE SUPPLY

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TABLE 1. Keithley Model 245 Specifications.

OUTPUT:
Voltage: 0 to 2100 volts dc in 10-volt steps.
Current: 10 milliamperes dc maximum.
Polarity: Positive or negative with respect to chassis.

ACCURACY: ±1% of dial setting.

RESOLUTION: A potentiometer permits interpolation between steps with a resolution better than 50 millivolts.

STABILITY: ±0.01% ±2 millivolts the first hour or in subsequent 8-hour periods, after a 1-hour warm-up.

LINE REGULATION: 0.001% plus 2 millivolts for 10% change in line voltage.

LOAD REGULATION: 0.002% plus 2 millivolts from no load to full load.

RIPPLE AND NOISE: Less than 1 millivolt rms above 5 cps.

OVERLOAD: Electronic current limiting to less than 13 milliamperes. Automatic recovery from overload within 1 second.

METER: Provides check on output and polarity.

CONNECTORS: Output (front and rear panel): MHV series (UG-931/U).

POWER: 105-125 or 210-250 volts (switch selected), 50-60 cps, 85 watts.

DIMENSIONS, WEIGHT: 5¼" high x 19" wide x 10" deep; net weight, 18 pounds.

ACCESSORIES SUPPLIED: Mating connector.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL. The Keithley Model 245 is a high voltage supply which provides accurate, stable outputs from 0 to 2100 volts dc. Accuracy is ±1% of the dial setting for all outputs. Stability is ±0.01% ±2 millivolts the first hour or in subsequent 8-hour periods, after a 1-hour warm-up. Line regulation is 0.001% plus 2 millivolts for a 10% change in line voltage, and load regulation is 0.002% plus 2 millivolts from no load to full load.

1-2. FEATURES.

a. Three in-line calibrated dials set the output voltage in 10-volt steps. The fourth dial is a potentiometer that permits interpolation between steps with 50-millivolt resolution. Output can be selected positive or negative with respect to ground.

b. Repeated overloading or operation in an overload condition for long periods will not damage the Model 245. Overload protection limits the output current to less than 13 milliamperes and, when the overload is removed, automatically returns the Supply to its set value.

c. The circuit for the Model 245 takes advantage of the reliability and stability of a solid-state comparator amplifier, and the high voltage capability of a series regulator tube to provide a high performance circuit. Metal-film range resistors and a selected zener diode contribute to its overall accuracy and stability.

1-3. APPLICATIONS.

a. The Model 245 is an ideal high voltage biasing supply for photomultiplier tubes, ion chambers, photocells and other current detectors. It is also suited for use in applications such as voltage gradient studies, surface and volume resistivity measurements and capacitor leakage measurements.

b. The output of the Voltage Supply may be remotely controlled or programmed by adding connectors to the rear panel. Mounting holes are provided to easily modify the Model 245.

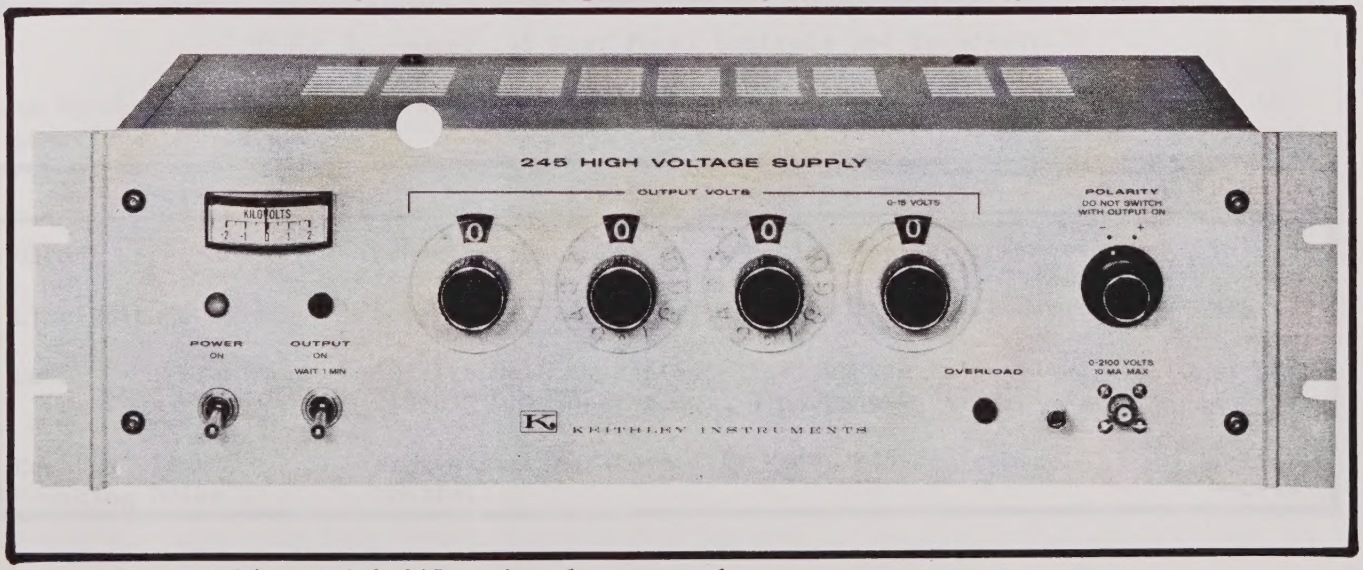


FIGURE 1. Keithley Model 245 High Voltage Supply.

TABLE 2. Model 245 Front Panel Controls and Terminals (Figure 2).

The Table briefly describes each control and indicates the paragraph which contains instructions on the use of the control.

Control	Functional Description	Par.
POWER ON Switch	Turns on line power to all circuits except high voltage: low voltage regulators, amplifier, tube filament and screen supplies.	2-2
POWER ON Pilot Light	Glows orange to indicate that all low voltage circuits are on.	2-2
OUTPUT ON Switch	Turns on line power to high voltage transformer activating all high voltage circuits.	2-2,2-4 2-7
OUTPUT ON Pilot Light	Glows red to indicate that both the POWER ON Switch and the OUTPUT ON Switch are on.	2-2
Voltage Dials	Sets output voltage from 0 to 2100 volts dc.	2-2,2-4,2-5 2-7
Trim Control	Interpolates between 10-volt settings of the voltage dials; 50 mV resolution, 15 volt range.	2-3,2-4
POLARITY Switch	Selects positive or negative outputs.	2-2
Output Receptacle	Connects Model 245 to accepting device.	---
Binding Post	Auxiliary ground connector for convenience & safety.	---
OVERLOAD Lamp	Glows to indicate output current exceeds approximately 11 mA.	2-3,2-5
METER	Indicates magnitude & polarity of voltage output.	---

TABLE 3. Model 245 Rear Panel Controls and Terminals.

The Table briefly describes each control and indicates the paragraph which contains instructions on its use.

Control	Functional Description	Par.
Output Receptacle	Connects Model 245 to accepting device.	---
Line Voltage Switch	Sets Model 245 for 117 or 234-volt power lines.	---
Fuse	105-125 volt operation: 1.25 ampere, slow-blow. 210-250 volt operation: 0.6 ampere, slow-blow.	---
Covered Blank Mounting Holes	Provides access to modify Model 245 for remote control.	2-10 —2-16

SECTION 2. OPERATION

2-1. CONNECTIONS.

a. The Model 245 Output receptacle is an MHV Teflon-insulated receptacle, the shell of which is connected to chassis ground. The binding post on the front cover allows additional ground connections to be made for added safety or convenience.

b. Use coaxial cables to insure good circuit connections and safe operation. Use Teflon or polyethylene-insulated connectors and cables which will withstand more than 2500 volts, such as RG58/U. Inspect insulation for mechanical or heat damage.

c. Coaxial cables also have the best noise characteristics. If noise is not important, unshielded leads may be used since the output impedance at low frequencies is very low.

d. For safety, use the 3-wire power cord to connect power lines. Make sure the third wire is connected to a good earth ground.

WARNING

If ground loops in the path of the system prevent connection to a good earth ground, then the ground lead need not be connected as long as safe operation is possible. That is, as long as the Model 245 isn't driving an instrument that is off ground. If the system is such that driving an instrument at off ground is non-preventable, make sure that the instrument is capable of floating at the desired level. Otherwise, the instrument chassis will be off ground.

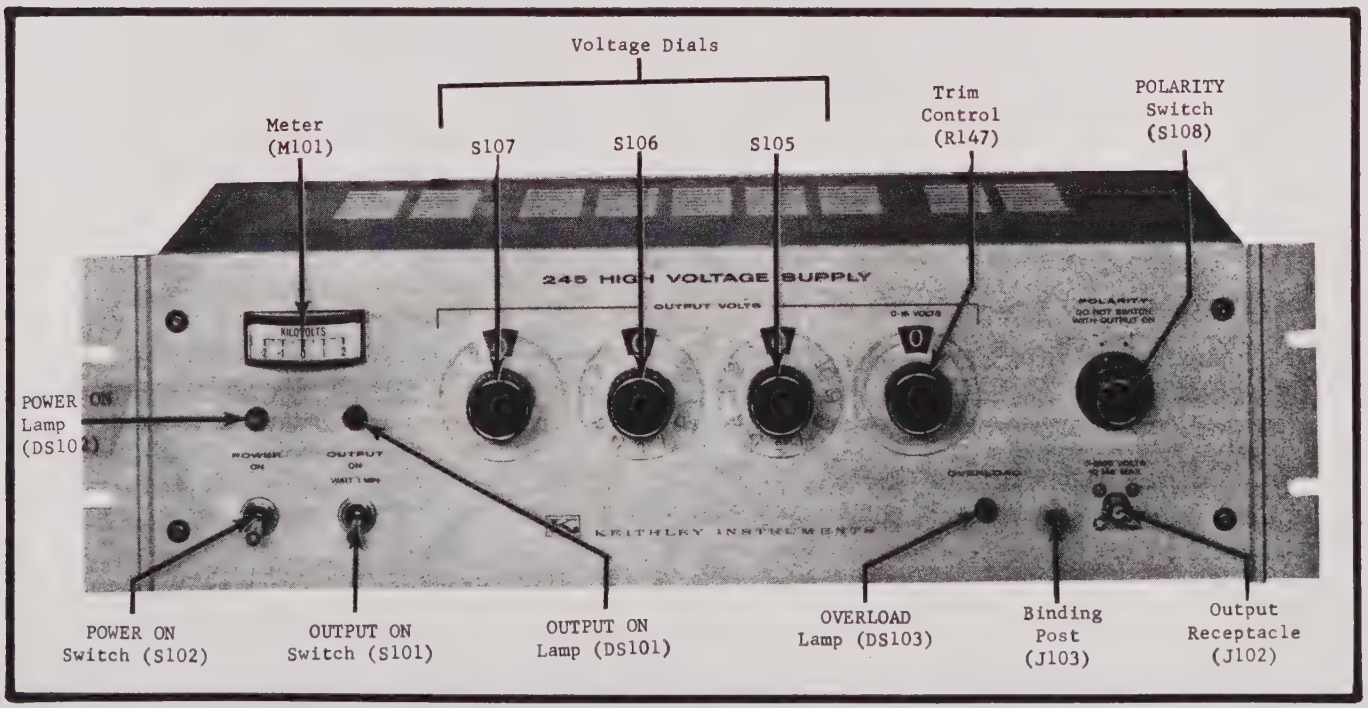


FIGURE 2. Model 245 Front Panel Controls and Terminals. Circuit designations refer to Replaceable Parts List and schematic diagrams.

2-2. PRELIMINARY PROCEDURES.

a. The Model 245 is shipped in operating condition with all components installed.

b. Check the 117-234 Volt Switch and the Fuse for the proper line voltage.

c. Make sure the Voltage supply will be properly ventilated when it is operating. Air flow should be available from the bottom, top, rear and both sides.

NOTE

If the natural flow of cool air is constricted in any way, the internal temperature of the Model 245 will rise and the life of many critical components will be shortened.

d. Set the front panel controls to:

POWER ON Switch	off
Voltage and Trim Switches	0 0 0 0
OUTPUT ON Switch	off
POLARITY Switch	+ or -

Plug the power cord into the power line. Turn the POWER ON Switch 'on'. The POWER ON Switch turns on the power for the low voltage regulators, the amplifier and the tube filament and screen supplies. The POWER ON Pilot Light will glow orange.

e. Allow the pass tube filament to warm up for about one minute.

f. Turn the OUTPUT ON Switch to 'on' and allow the Model 245 to warm up for 30 minutes. The OUTPUT ON Switch turns on the line power to the high voltage transformer and therefore activates all high voltage circuits. Turning off this switch removes the output power within a short time. To insure maximum life of the high voltage tube, it is necessary to wait about one minute after turning on the POWER ON Switch before the OUTPUT ON Switch is turned on. To prevent damage the high voltage output switch is wired in series with the POWER ON Switch so that the high voltage cannot be turned on before the low voltage is turned on. The OUTPUT ON Pilot Light will glow red.

CAUTION

If there is no voltage dialed on the 100 volt range, avoid turning the left most Voltage Dial, the 1000-volt range switch, from '1' to '0' when the OUTPUT ON Switch is on. Turning this Dial causes arcing across the range switch and eventually will damage it.

CAUTION

Do not switch the POLARITY Switch when the OUTPUT ON Switch is on. Arcing across the POLARITY Switch will occur and damage will ensue.

g. The operating checks, paragraph 2-3, may be performed if desired.

2-3. OPERATING CHECKS.

a. Zero Balance. Connect the Keithley Model 153 Microvolt-Ammeter or an equivalent instrument to the Model 245 OUTPUT Receptacle. With the Voltage Switches at 0000 and the

OUTPUT Switch at -, after 30 minutes the output voltage should be less than ±1 millivolt. If it is more, see paragraph 5-3.

b. Output Voltage. Decrease the Model 153 sensitivity to 100 volts or more. Set the Model 245 Voltage Dials to an output equal to full scale on the voltmeter. Make sure the Trim Control is set to "0". If the output is not within the accuracy of both instruments, see paragraph 5-4.

c. Current Limit.

1. Use the Model 153 as an ammeter and connect it to the Model 245 OUTPUT Receptacle. Increase the Voltage Supply output using the Trim Control until the OVERLOAD Lamp lights Output current should be between -11 and -13 milliamperes. If not, see paragraph 5-5.

2. Set the Model 153 to its 30-milliampere range. (If another ammeter is used, its voltage drop must be less than 150 millivolts on a scale capable of reading 15 milliamperes.) Set the Model 245 output voltage to -100 volts. The OVERLOAD Lamp should light and the output current should be -12.5 ±0.2 milliamperes.

2-4. SETTING OUTPUT VOLTAGE.

a. The setting of the three Voltage Dials and the Trim Control determines the magnitude of the output voltage. The specified output accuracy and stability are assured only when the Trim Control is set to "0". At this setting, the Trim Control is disconnected from the output control circuit.

1. The three Voltage Dials set the output voltage from 0 to 2100 volts dc in calibrated 1000, 100 and 10-volt steps.

2. The Trim Control interpolates between 10-volt settings of the Voltage Dials with better than 50-millivolt resolution. The range of the Control is from 0 to 15 volts. The Control has a snap-action off position which is indicated by the fully visible "0". At this setting the Model 245 output is determined only using the Voltage Dials. When using the trim control a line appears across the "0" to show that the output voltage is somewhat greater than the direct dial readings.

b. To increase the output voltage less than 200 millivolts, reduce the Voltage Dial setting to 10 volts; then use the Trim Control in the upper portion of its range. The Control has an unusable portion at the very beginning of its range due to the switch action which defines the "0" position.

c. When the OUTPUT ON Switch is in 'off' position and the high voltage circuits are not activated there is still up to 300 volts applied to the amplifier and tubes.

NOTE

The output noise when the OUTPUT ON Switch is set to the 'off' position may be as much as 100 millivolts rms. This is typical and does not indicate a defective Voltage Supply.

2-5. OVERLOAD OPERATION.

a. A current limiting circuit provides overload protection for the Model 245. When output current exceeds approximately 10 milliamperes, the Model 245 enters a constant cur-

rent mode; the load resistance then determines the voltage across the load. For this mode. the OVERLOAD Lamp will light. Removing the overload or reducing the load automatically resets the Model 245 output to its original value and turns off the OVERLOAD Lamp.

b. The Model 245 is factory adjusted to deliver at least 10 milliamperes before the current limiting circuit operates. The OVERLOAD Lamp lights at about 11-milliampere output. Current limiting action, indicated by an increase in output noise, begins at about 11.5 milliamperes.

c. On a typical instrument, maximum short circuit output current can be adjusted anywhere between 7 and 17 milliamperes (paragraph 5-5). This provides a useful current output from about 5 to 15 milliamperes. However, operating the Model 245 at outputs greater than 10 milliamperes may degrade its load regulation specification for 2100-volt outputs and for low power-line voltages, and it may also degrade specifications at all output voltages.

NOTE

For output voltages and capacitive loads exceeding 1 joule of energy, never use the Voltage Dials to reduce the output more than 100 volts at a time or to go to zero output. Use the procedures given in paragraph 2-6 b.

2-6. CAPACITIVE LOADS.

a. Its current limiting circuit enables the Model 245 to charge capacitive loads without difficulty. The OVERLOAD Lamp will light during the time the output current exceeds 11 milliamperes, but the current continues to flow. The Model 245 High Voltage Supply does not have to be continually reset while charging a capacitive load.

b. For capacitive loads exceeding 1 joule of energy, change the Model 245 output by first setting the OUTPUT ON Switch to 'off'. Then readjust the Voltage Dials and turn the OUTPUT ON Switch to 'on'. Reducing the output voltage without setting the OUTPUT ON Switch to 'off' could damage the ranging resistors and/or the voltage selection switches.

c. A large capacitive load may cause a resonant condition when the Model 245 output polarity is negative and when excessive line transients are present. Under this condition an increase in output capacity will increase the Model 245 output noise slightly. Then, as more capacity is added to the output, the output noise is reduced to its normal level.

2-7. OUTPUT NOISE. When the Model 245 operates with no load and from a clean power line, typical output noise at any voltage setting will be less than 20 millivolts peak-to-peak or 0.5 millivolts rms. Transient noise on the power line will tend to increase the peak-to-peak output noise, and if it is sufficiently high, may cause rms output noise to also increase. As the output current increases, output noise decreases to about 10 millivolts peak-to-peak. (Refer also to paragraph 2-6c.)

2-8. SHORT-TERM STABILITY. After a 3-hour warm-up the short term stability of the Model 245 is typically better than 0.003% per hour for output voltages greater than 100 volts and with constant line voltage, load and ambient temperature.

2-9. TEMPERATURE COEFFICIENT. The temperature coefficient of the Model 245 output voltage depends primarily upon the temperature coefficients of the zener reference, the voltage divider resistors and the voltage control comparator circuit. Using the maximum values for these components, the maximum temperature coefficient for the voltage supply is ± 290 ppm/^{o}C or $\pm 0.029\%/^{o}$C. Typically, the coefficient will be much lower (around 50ppm/^{o}C).

2-10. REMOTE PROGRAMING.

a. Remote programing or control of the Model 245 is possible using one of two methods: resistance programing or voltage programing. The Model 245 can be modified for only one of these methods at a time, however. The modifications do not have to be permanent and the Model 245 can be easily returned to normal.

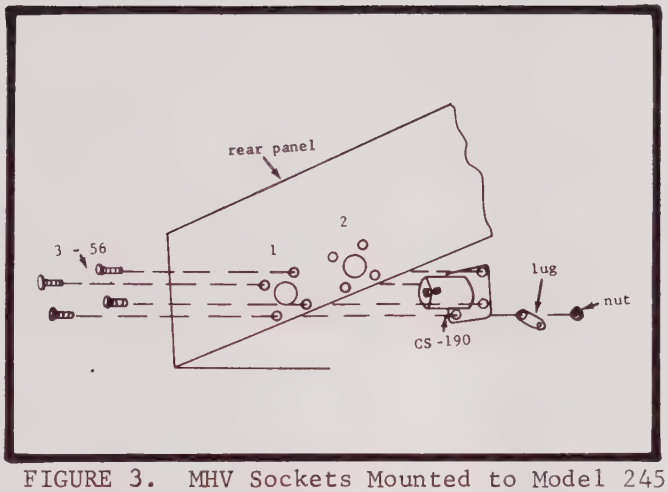


FIGURE 3. MHV Sockets Mounted to Model 245. The sockets, located in the rear panel, are used for remote programing.

b. Resistance programing is useful where accurate output voltages are needed in a fixed sequential order. External resistors are added in series with the resistors in the Voltage Dials. This allows remote control of the Model 245 output. In this method, the Model 245 output is set to the minimum operating voltage needed. Besides the external resistors, parts required for this modification are two MHV connectors and 19-1/2 inches of shielded cable.

c. Voltage programing is a non-linear high-gain system of output voltage control. It is useful where the Model 245 is to maintain constant some system parameter other than the supply voltage. In this method, the Model 245 Output Voltage Dials are set to the maximum output voltage desired. A positive input voltage to the modified Voltage Supply causes the output voltage to decrease in magnitude. This modification is used only for negative output voltages. Parts required for this modification are two MHV connectors, 14 inches of cable, a resistor and a diode.

2-11. MODEL 245 MODIFICATIONS FOR RESISTANCE PROGRAMING.

a. Remove the plate over the punched holes on the Model 245 rear panel. These holes accept MHV connectors (No. UG-931/U, manufactured by most connector companies; Keithley part number CS-190). Mating connectors are UG-932/U (manufactured by most connector companies; Keithley part number CS-191). Use a lug to ground the shields of the cables to the Model 245 chassis as shown in Figure 3. Use 3-56 screws and nuts to fasten the connectors to the rear panel; if not available, 2-56 screws and nuts are sufficient. Relocate the ac wires at the inside rear panel so that the connectors can be installed.

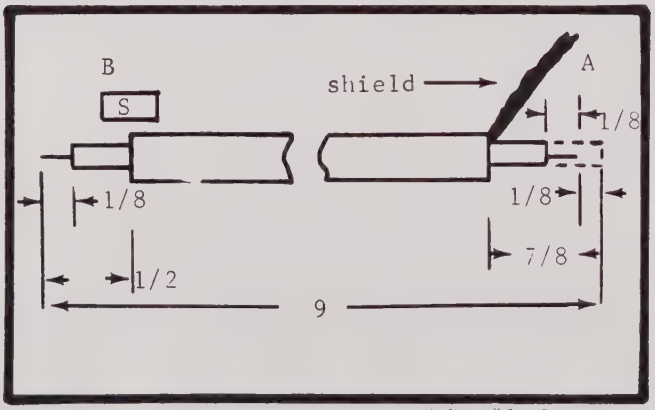


FIGURE 4. Dimensions for Cable #1 for Resistance Programing. Dimensions are in inches.

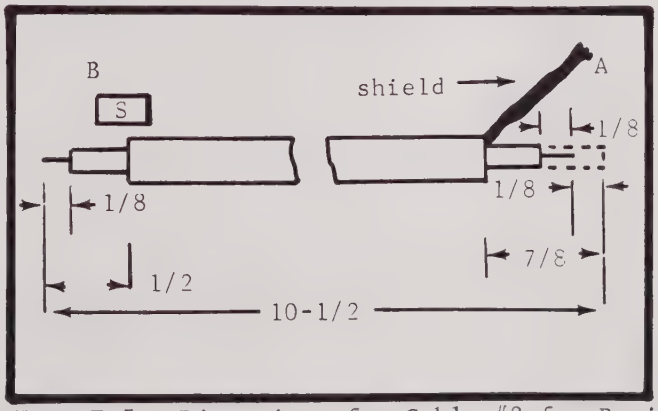


FIGURE 5. Dimensions for Cable #2 for Resistance Programing. Dimensions are in inches.

b. Prepare the 9 inch cable #1 as shown in Figure 4.

1. Use shielded, single conductor cable with insulation which will withstand at least 2500 volts. The conductor should be #25 wire or larger.

2. From end A cut off 7/8 inch of outer insulation only. Comb out the shield and wrap together. Cut off 1/8 inch of center insulation and conductor. Cut off 1/8 inch of insulation, baring 1/4 inch of wire.

3. From end B cut off 1/2 inch of outer insulation and shield. Use 3/4 inch of shrink tubing over the end as shown in Figure 4. Cut off 1/8 inch of insulator, baring 1/8 inch of wire.

c. Prepare the 10-1/2 inch cable #2 in the same manner as cable #1. Refer to Figure 5.

d. Connect the cables to the connector.

1. Attach the center conductor of Cable #1 (end A) to the center pin of connector #2 (refer to Figure 3). Connect the shield of the cable to the ground lug.

2. Remove the green wire that runs from eyelet #1 on the range resistor PC board, (PC-130, Figure 18) to the Trim Potentiometer, R147.

3. Attach end B of Cable #1 to eyelet #1 on PC-130, Figure 18.

4. Attach the center conductor of Cable #2 (end A) to the center pin of connector #2. Connect the shield of the cable to the ground lug.

5. Attach end B of Cable #2 to the center terminal of the Trim Potentiometer, R147.

2-12. CIRCUIT FOR RESISTANCE PROGRAMING.

a. The accuracy and stability of the external resistors connected in series with the Model 245 sampling resistors will determine the accuracy and stability of the output voltage. These should be similar in specifications to resistors R148 to R177 in the Model 245: 0.5%, 1/2-watt metal film resistors (Keithley Part No. R61). It is also recommended that the resistors be power derated five to ten times.

b. The programing constant for the external resistors is 1000 ohms per volt. The current remains a constant 1 milliampere. Increasing the output voltage 10 volts requires increasing the external resistance 10 kilohms. For example, to remotely increase the Model 245 output 600 volts requires increasing the external resistance 600 kilohms.

c. In establishing an output sequence, do not go from a high voltage to a voltage near zero. There is a large amount of capacitive energy that must be carried by the remote range switches and damage to switches may result. If it is necessary to switch to zero, consult paragraph 2-6 on capacitive loads.

d. Make sure the remote range circuit is never at open circuit. This permits the Model 245 output voltage to increase above 2100 volts, which could damage the Voltage Supply. Always use a make-before-break remote switching sequence.

NOTE

Use sufficient insulation because the voltage control is in the negative output voltage side of the Model 245.

2-13. OPERATION FOR RESISTANCE PROGRAMING.

a. Connect the external resistors between the center pins of the two MHV connectors.

b. Set the Model 245 front panel controls to:

POWER ON Switch	on
OUTPUT ON Switch	on
Voltage and Trim Switches	0 0 0 0
POLARITY Switch	- or +, as desired.

c. The minimum output voltage for any setting of the external resistors will be the setting of the Voltage Dials. If zero output is not needed, then set the Voltage Dials to the desired value. All outputs will increase an equal amount. If the Dials are set to 100 volts, all outputs determined with the external resistors will increase 100 volts.

CAUTION

Make sure the center pins of the two connectors are not left open circuit. The output voltage may rise to approximately 3000 volts; damage may result to the Model 245 or to the load.

d. To return the Model 245 to normal operation, short together the center terminals of the two MHV connectors, or remove the leads and replace the green wire.

2-14. MODEL 245 MODIFICATIONS FOR VOLTAGE PROGRAMING.

a. Remove the plate over the punched holes on the Model 245 rear panel. These holes accept MHV connectors (No. UG-931/U, manufactured by most connector manufacturers; Keithley part number CS-190). Mating connectors are UG-932/U (manufactured by most connector manufacturers; Keithley part number CS-191). Use a lug to ground the shield of the cables to the Model 245 chassis as shown in Figure 3. Use 3-56 screws and nuts to fasten the connectors to the rear panel; if not available, 2-56 screws and nuts are sufficient. Relocate the ac wires at the inside rear panel so that the connectors can be installed.

b. Prepare the 7-inch cable #3 as shown in Figure 6 and the 8-inch cable #4 as shown in Figure 7.

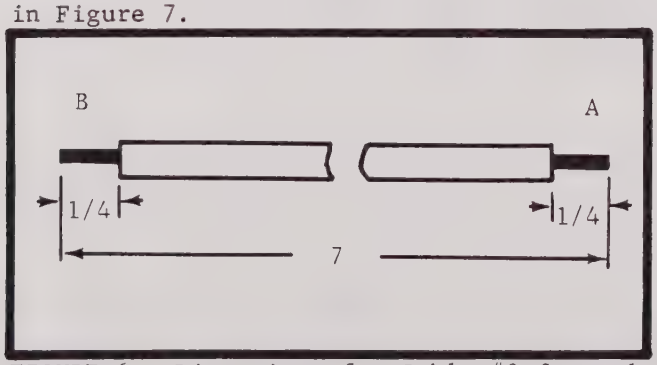


FIGURE 6. Dimensions for Cable #3 for Voltage Programing. Dimensions are in inches.

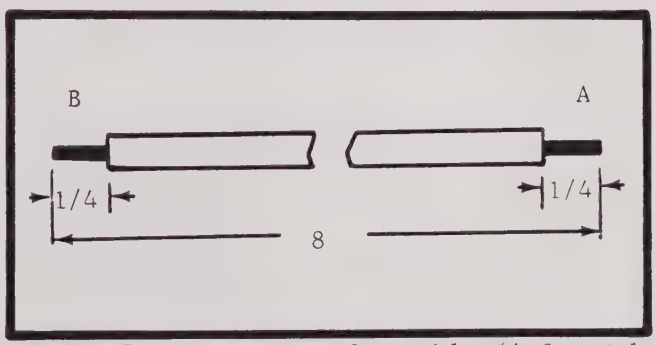


FIGURE 7. Dimensions for Cable #4 for Voltage Programing. Dimensions are in inches.

1. Use unshielded cable with insulation which will withstand at least 3500 volts. The conductor should be #22 wire or larger.

2. Cut off 1/4 inch of insulation from each end (A and B) of both cables #3 and #4.

c. Connect the cables to the connector.

1. Attach either end of cable #3, the 7-inch cable, to connector #2 (Figure 3).

2. Attach either end of cable #4, the 8-inch cable, to connector #1 (Figure 3).

3. Connect the other end of cable #3 to eyelet #17 on the Model 245 PC Board PC-131, Figure 14.

4. Connect the other end of cable #4 to eyelet #18 on the Model 245 PC board PC-131, Figure 14.

2-15. CIRCUIT FOR VOLTAGE PROGRAMING.

a. Since each particular supply will be different, no definite values may be given for system operation or stability. These must be checked for the particular application.

b. The Model 245 Voltage Dial setting determines the maximum output voltage. The remote control voltage reduces the output voltage below this maximum value. This protects the Model 245 and loads whose voltage rating may not be exceeded.

c. The load current drawn and the remote control voltage determine the lower voltage range. Attempting to use outputs less than 100 volts results in large non-linearities. It is recommended that at least 0.5-milliampere load current be present at 100 volts, requiring at least 5-milliampere load current at 2000 volts.

TABLE 4.

Typical Programing Coefficient for Voltage Programing. The Model 245 is set for -2000 volts; the load is a 200-kilohm resistive load. The value of R_S (Figure 8) is 1000 ohms. Changing the circuit will change the coefficient.

Control Voltage, volts	Output Voltage, volts
0	-2000
+5.33	-1750
+5.58	-1500
+5.68	-1250
+5.75	-1000
+5.83	- 500

d. The circuit for voltage programing includes a 1000-ohm resistor, R_S, between the external control voltage and the Model 245 (see Figure 8). The value of R_S may be reduced below 1000 ohms, but if the external control voltage becomes too large the Model 245 may be damaged.

e. Since the Model 245 is operating in a condition which is somewhat analogous to an open loop, there is high gain from the control terminals to the output terminals. The programing coefficient will vary; Table 4 presents a typical example. The coefficient for any circuit must be determined for the particular application.

f. If the control voltage is a step function, the ranging speed is a function of resistive and capacitive loading, and it is approximately exponential.

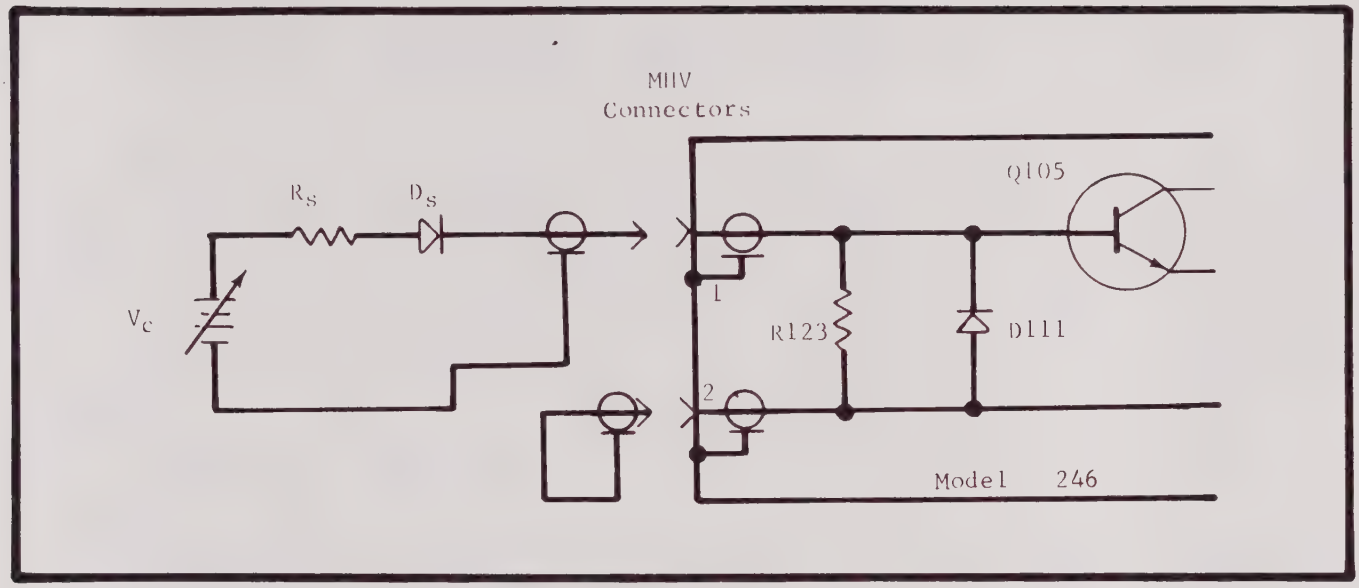


FIGURE 8. Circuit for Voltage Programing. The external control voltage, V_C, is connected to the MHV connectors through a 1000-ohm resistor, R_S, and diode D_S. Cables 3 and 4 connect the external voltage to the printed circuit board within the Model 245.

2-16. OPERATION FOR VOLTAGE PROGRAMING.

a. Short terminal of connector 2 to chassis. Connect a diode and resistor to connector 1 as shown in Figure 8. Normally, use a 1000-ohm, 1/2 watt resistor. The diode (1N645) prevents the Model 245 output voltage from exceeding the dialed supply voltage if the external control voltage becomes negative.

b. Set the Model 245 front panel controls to:

POWER ON Switch	on
OUTPUT ON Switch	on
Voltage and Trim Switches	Desired Output
POLARITY Switch	(-)

If the POLARITY Switch is set to +, the Voltage supply will be shorted and the OVERLOAD Lamp will light. In - output, the OVERLOAD Lamp functions normally.

c. To return the Model 245 to normal operation, disconnect the two mating connectors from the rear of the instrument. Internal cables #3 and #4 may or may not be removed.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The Keithley Model 245 High Voltage Supply furnishes outputs from 0 to 3100 volts dc. The block diagram (Figure 9) shows the relationship between operating circuits. Setting the sampling resistors in the voltage divider selects the output voltage. Any difference between the voltage drop across a string of calibrating resistors and the zener reference is sensed by the voltage control comparator and amplified. The amplified difference signal is returned to the series regulator. This maintains the output voltage at a constant level determined by the divider ratio selected with the front panel Voltage Dials. The current limit comparator and amplifier prevents the output current from exceeding 13.0 milliamperes.

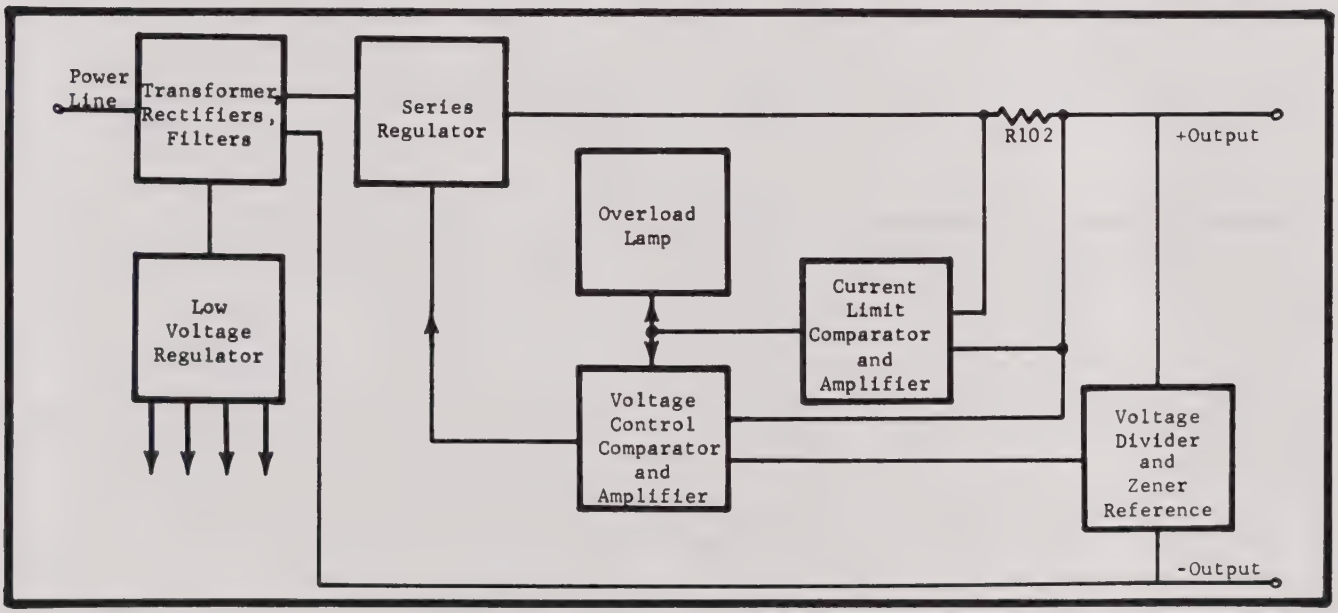


FIGURE 9. Model 245 Block Diagram.

NOTE

Refer to Schematic Diagram 21581E for circuit designations.

3-2. HIGH AND LOW VOLTAGE SUPPLIES.

a. High voltage for the series regulator tube is obtained using a voltage doubler circuit, composed of diodes D102 and D103 and filter capacitors C101 and C102. This circuit increases transformer life and reduces corona.

b. Low voltage for the control circuitry is obtained from rectifiers D104 and D105 and filter capacitors C106 and C107. Cascaded regulators V103, V104 and D107, D108 regulate this voltage.

3-3. VOLTAGE CONTROL. The voltage divider consists primarily of zener reference D116, the sampling voltage divider, R148 to R177, and the calibrating resistor divider, R135 to R139. See Figure 10.

a. The front panel Voltage Dials, S105 to S107, set the value of the sampling resistors. Changing the sampling resistors, R148 through R177, varies the output voltage. The output voltage, E_o (Figure 10), assumes a value such that the voltage drop across the calibrating resistors, R135 to R139, is equal to the voltage of the zener reference, D116. The voltage control comparator and amplifier sense any difference between these voltages and correct the voltage, E_i, through the series regulator V101. Resistors R106 through R110 insure that a 3 to 2 voltage ratio occurs across the tubes.

b. The voltage control comparator and amplifier consists of a differential amplifier (transistors Q105 and Q106), a current amplifier (transistor Q104), and a voltage amplifier (transistors Q102 and Q103). Its output controls the voltage across the cathode biasing transistor Q101 of the series regulator tube, V101. Diodes D111 through D116 and resistors R123, R132 and R133 protect the voltage control comparator and the zener reference from switching transients when the output voltage is changed. Diode D110 prevents a reverse bias on the current amplifier Q104 beyond its breakdown voltage.

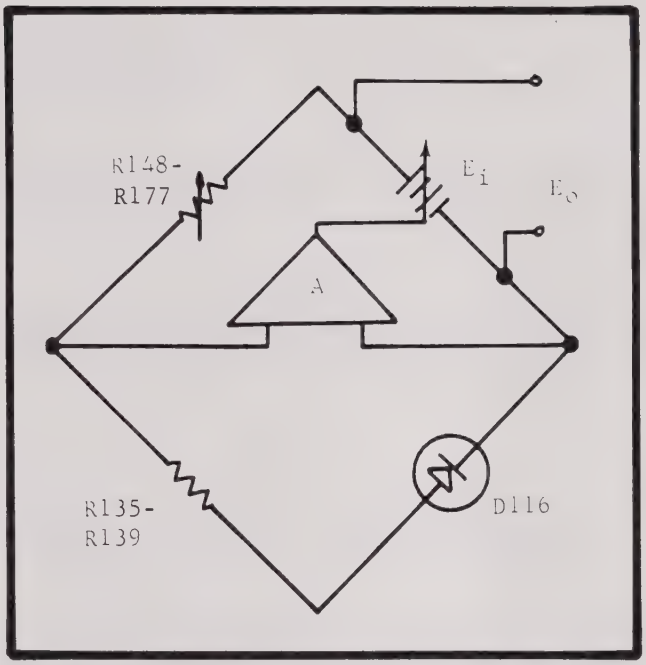


FIGURE 10. Diagram of Voltage Control Comparator. R148 to R177 are the sampling resistors set with S105 to S107. R135 to R139 are the calibrating resistors. E_i is the voltage through the series regulator, V101. E_o is the Model 245 output voltage. A is the voltage control comparator and amplifier

3-4. OUTPUT VOLTAGE. The Polarity Switch, S108, grounds one side of the Voltage Supply and connects the other side to the parallel Output Connectors, J101 and J102. An additional ground terminal, J103, can be used for grounding.

3-5. CURRENT CONTROL.

a. The output current is sensed by measuring the voltage drop across resistor R111. A current limit comparator and differential amplifier, transistors Q107 and Q108, compares this voltage to that at the tap of potentiometer R130.

b. The comparator controls the OVERLOAD Lamp, DS103, and the Voltage Supply operating mode: normal, when there is no overload on the Moder 245, and current limited, when the output current exceeds 10 milliamperes. Selection between modes occurs automatically using a switch composed of diode D109 and the base-emitter of transistor Q104. In the normal mode, the voltage on the anode of diode D109 is less than the voltage on the base of Q104. Therefore, Q104 conducts and Q109 does not. In the current limit mode, the voltage on the anode of D109 is higher than that on the base of Q104. D109 conducts and Q104 does not.

c. The neon OVERLOAD Lamp, DS103, is switched on by transistor Q110 turning off. As the lamp begins to ignite, Q110 is turned off, causing the lamp to come on to full brilliance. Base current for transistor Q110 is supplied by transistor Q109.

SECTION 4. SERVICING

4-1. GENERAL. This Section contains the maintenance and troubleshooting procedures for the Model 245 Voltage Supply. Follow these as closely as possible to maintain the specifications of the instrument.

4-2. SERVICING SCHEDULE. The Model 245 needs no periodic maintenance beyond the normal care required of high-quality electronic equipment. Occasional checks of the output, described in Section 5, will show the need of any adjustments. No part should need frequent replacement under ordinary use.

4-3. PARTS REPLACEMENT.

a. The Replaceable Parts List in Section 7 describes the electrical components of the Voltage Supply. Replace components only as necessary. Use only reliable replacements which meet the specifications.

b. The zener diode, D116, is selected as are diodes D112 and D113; transistors Q105 and Q106 are a matched pair. Order these replacements only from Keithley Instruments, Inc., or its representative, as well as other parts marked for Keithley manufacture (80164) in the Replaceable Parts List.

TABLE 5.

Equipment Recommended for Model 245 Troubleshooting and Calibration. Use these instruments or their equivalents.

Instrument	Use
Ballantine Model 320A Wideband, True RMS VTVM, 100 microvolts to 330 volts, 5 Hz to 4 MHz	Check output noise
Keithley Instruments Model 153 Microvolt-Ammeter, 10 microvolts to 1000 volts, ±1% at 3 millivolts; 200-megohm input resistance, 10^{-11} to 0.1 ampere	Circuit checking
Keithley Instruments Model 610B Electrometer, 10^{-3} to 100 volts, 10^{-14} to 0.3 ampere, 10^{2} to 10^{14} ohms; 10^{14} ohm input resistance	Circuit checking
Keithley Instruments Model 662 Differential Voltmeter, ±0.01% limit of error, 100 microvolts to 500 volts	Calibrating output voltage
Keithley Instruments Model 6601A 100:1 Divider, ±0.01% accuracy	Used with Model 662 above 500 volts
Tektronix Model 504 Oscilloscope	Check output noise

TABLE 6. (Sheet 1)

Model 245 Troubleshooting. Read paragraph 4-5 before performing any repairs.

Trouble	Probable Cause	Remedy
No output voltage, pilot light off	Line cord not plugged in	Plug in line cord
	117-234 Switch not correctly set	Set Switch correctly
	POWER ON or OUTPUT ON Switch off	Turn both switches on
	Fuse F101 Blown	Replace fuse; if fuse repeatedly blows, check further.
No output voltage, repeated fuse failure	V101, V103, V104 or associated circuitry faulty	See paragraph 4-6
No output voltage but pilot light on	Trouble in high or low power supplies or tube filament	See paragraph 4-6
	Faulty V101	Check, replace if faulty
	Current limiting or voltage control amplifiers defective	See paragraphs 4-7 and 4-8
Output voltage not correct by an approximately constant amount	Zero potentiometer not set	See paragraph 5-3
	Voltage control amplifier will not zero	See paragraphs 4-7 and 4-8
	Output noise high	See paragraph 4-10, 2-7
Output voltage not correct by an approximately constant percentage of Voltage Dial setting	CAL potentiometer not set	See paragraph 5-4
	Diodes D112, D113, D114 or D115 leaking	Check, replace if faulty
	Faulty Q106	Check, replace if faulty
	Zener D116 or R135, R136, R137 R138 or R139 faulty	Check, replace if faulty
Output voltage not correct for low voltage outputs only	Amplifier not balanced	See paragraphs 4-7 and 4-8
	Output noise high	See paragraph 4-10
Output voltage not correct at only a few dial settings	Switches S105, S106 or S107 or one of resistors R148 to R177 faulty	Return to factory for repair

TABLE 6. (Sheet 2)

Model 245 Troubleshooting. Read paragraph 4-5 before performing any repairs.

Trouble	Probable Cause	Remedy
Output not correct at high voltage outputs only	High voltage transformer, rectifiers or filters faulty	See paragraph 4-6
	C114 or C115 leaking	Check, replace if faulty
	V101 circuit open or tube faulty	Check, replace if faulty
	Amplifier swing not sufficient	See paragraphs 4-7 and 4-8

4-4. TROUBLESHOOTING.

a. The procedures which follow give instructions for repairing troubles which might occur in the Model 245. Use the procedures outlined and use only specified replacement parts. Table 5 lists equipment recommended for troubleshooting. If the trouble cannot be located or repaired, contact Keithley Instruments, Inc., or its representative.

b. Table 6 lists problems which might occur. If the repair indicated does not work, check through each circuit as described in the following paragraphs. Refer to the description in Section 3 to understand the circuits. The complete circuit diagram, 21581E, is in Section 7.

WARNING

Use extreme caution when working within the Model 245. High voltages are present at many points. Before removing the cover, make sure the power cord is disconnected. After removing the cover, discharge all metal cased capacitors before proceeding with repairs. Discharge all high voltages through a bleeder.

4-5. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. Always set the OUTPUT Switch to - when working on the Model 245. This keeps the voltage control amplifier ground at case potential. When the POLARITY Switch is at +, the series regulator low is above case ground by the amount of the output voltage.

b. Before troubleshooting the Voltage Supply, check the external circuits. Check the fuse, power cord and power source.

c. The schematic diagram 21581E contains the voltages at selected points. These were measured with the Model 153 to ±15%, and with the Model 245 controls set to:

POWER ON Switch	on
OUTPUT ON Switch	on
Voltage Dials and Trim Control	0 0 0 0
POLARITY Switch	(-)

d. Check the vacuum tube, V101, and the gas tubes, V103 and V104. Check tubes by replacing them. Normally, replacing tubes will clear up any difficulty.

4-6. TRANSFORMER CHECK. If no output voltage appears and if the fuse repeatedly blows, follow these procedures.

a. Removing tube V101 (Figure 13) from the socket unloads the high voltage and filament winding of the transformers.

b. Removing Tubes V103 and V104 (Figure 16) from their sockets unloads the low voltage winding of the low voltage transformer.

c. If the fuse continues to blow, the trouble is in the rectifiers, filters, transformers or wiring. The best approach is to disconnect all secondary leads and check the transformer using the Model 610B as an ohmmeter.

4-7. TROUBLESHOOTING THE VOLTAGE CONTROL AMPLIFIER.

a. To troubleshoot the voltage control amplifier, first remove the high voltage by turning the OUTPUT ON Switch to 'off'. Remove tube V101 (Figure 13) from its socket and disconnect the plate cap. Make sure the plate cap is clear of all surrounding components. Place a shorting jumper across either diode D112 or D113 (Figure 16).

b. Set the front panel controls to:

POWER ON Switch	off
OUTPUT ON Switch	off
Voltage Dials and Trim Control	0 0 0 0
POLARITY Switch	(-)

Do not connect anything to the Output Receptacles.

c. Connect the Model 153 between the base of transistor Q101 and ground. Turn the Model 245 POWER ON Switch to 'on'. Adjust the ZERO potentiometer R125 (Figure 17). Turning the potentiometer should swing the voltage from approximately +1 to -1/2 volt.

d. If the voltage will swing from +1 to -1/2 volt, then the voltage control amplifier will balance at dc and it is probably functioning properly. If it will not swing from +1 to -1/2 volt, the trouble may be in either the voltage control amplifier or in the current limit circuit. See paragraph 4-8.

4-8. TROUBLESHOOTING THE CURRENT LIMITS CIRCUITS.

a. A defective current limit circuit can interfere with the voltage control amplifier. First, see if the voltage control amplifier is operating correctly (paragraph 4-7).

b. Set the front panel controls as in paragraph 4-7, b. Since there is no overload, there should be a reverse voltage across diode D109 (Figure 16). The amplifier should be in its normal mode.

c. If there is not a reverse voltage across D109, disconnect the current limit circuit by disconnecting one end of diode D109. If the voltage control amplifier does not yet balance the trouble is in the amplifier. If the voltage control amplifier balances, the trouble is in the current limit circuit. Locate the trouble by making voltage measurements within these circuits.

TABLE 7. Current Limit Circuit Voltages.

These values were measured with the Model 153 to ±15%. The Voltage Dials are set to 0000 and the POLARITY Switch to -. Voltages at points C, D and E depend on both zener voltages (D107 and D108). Zener Voltages range between 15 and 22 volts. The points C, D and E are indicated in Figure 11.

Zenner Supply Voltage (Pt. A)	Zener Supply Voltage Point B	Point C	Point D	Point E
+ 18 volts	-18 volts	-0.5 volts	-0.5 volts	+ 0 volts
to	to	to	to	to
22 volts	-22 volts	+0.8 volts	+4.0 volts	+1.4 volts

4-9. TROUBLESHOOTING THE OVERLOAD LAMP CIRCUIT.

a. Trouble in the OVERLOAD Lamp driver circuit is indicated by the lamp not lighting when the voltage control amplifier and the current limit circuit are working. The latter circuit is working if output noise increases as the overload increases and current limiting action occurs.

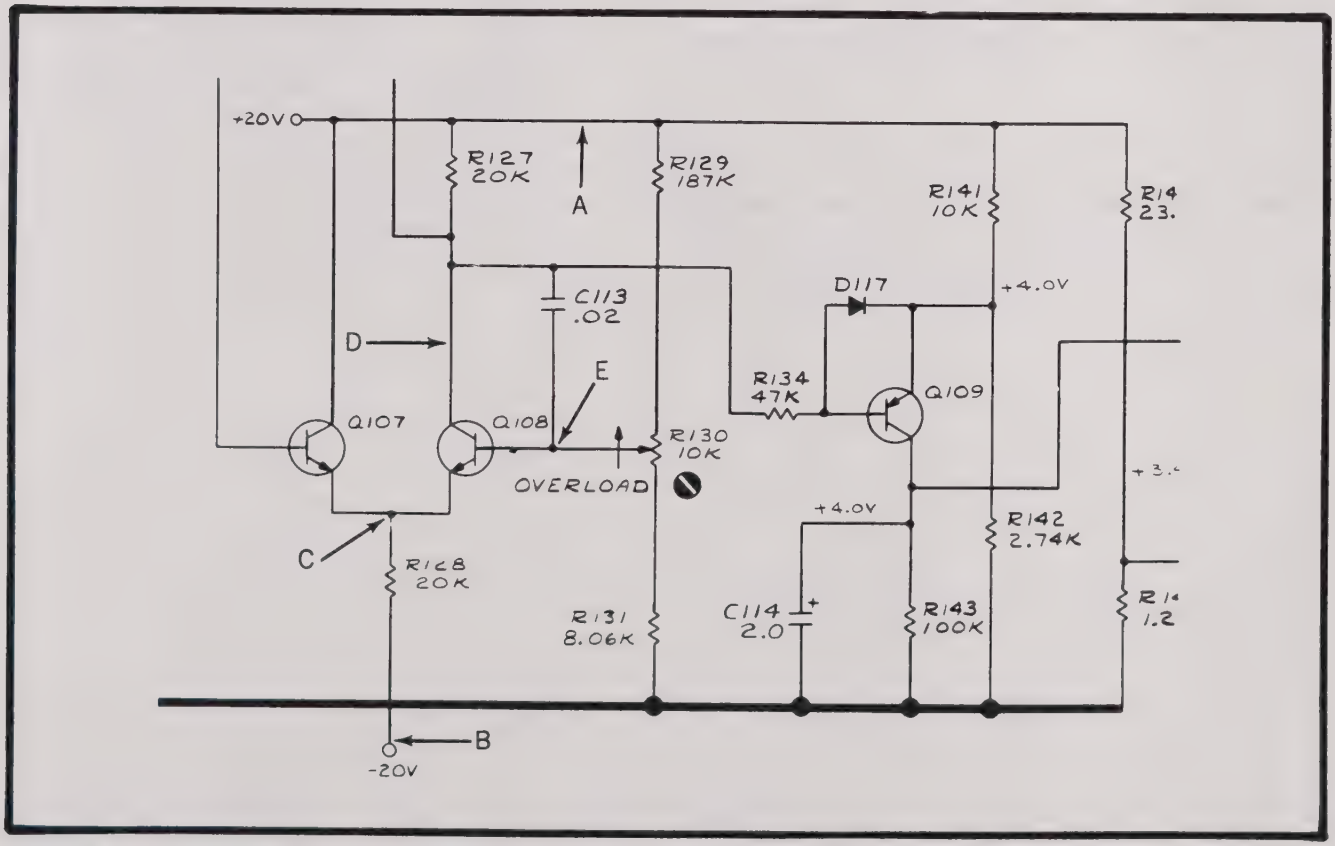


FIGURE 11. Voltage Points within Current Limit Circuit. Refer to Table 7 for values which depend upon the voltage at Points A and B.

b. In overload condition, the voltage between the emitter and collector of transistor Q110 (Figure 16) should be more than 105 volts. If it is and the lamp will not light, then the lamp is defective.

c. If 105 volts is not present, then either transistor Q109 or Q110 (Figure 16) or the associated circuitry is defective. Measure the voltages within the circuits to locate the trouble.

d. Voltages within the current limit amplifier vary considerably, depending upon the voltage across zener diodes D107 and D108. Nominally, the voltage at point A is +20 volts and at point B is -20 volts. Table 7 gives the approximate range for points C, D and E in Figure 11 for voltages within the limits of the zener if the instrument is working properly

4-10. OUTPUT NOISE. With a voltage setting of less than 600 volts, the output noise on the Model 245 may be read by connecting the Model 504 oscilloscope or the Model 320A voltmeter across the output terminals of the Model 245. With a voltage setting greater than 600 volts, use a blocking capacitor box (Figure 12) with the oscilloscope or voltmeter. When using the box keep the switch on the box closed except when reading noise. Excessive power line noise will tend to increase the output noise. The output noise should be less than 20 millivolts peak-to-peak or 1.0 millivolt rms. If the noise is higher, then most likely one of the regulator tubes V103 or V104 is defective. If replacing these tubes does not clear up the trouble, then either the pass tube, V101 is defective or one or more of the amplifier transistors, Q101 through Q106, is defective.

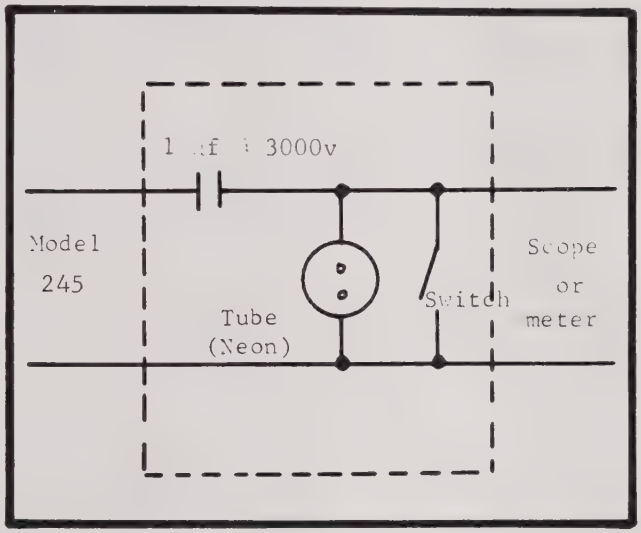


FIGURE 12. Blocking Capacitor Box Used With an Oscilloscope or Voltmeter to Read Output Noise on Model 245.

SECTION 5. CALIBRATION

5-1. GENERAL.

a. The following procedures are recommended for calibrating the Model 245. It is also recommended that the equipment listed in Table 5 be used. If difficulty is encountered, contact Keithley Instruments, Inc., or its representative.

b. Before performing any calibration, make sure the Model 245 is in working order. Allow it to stabilize for at least 30 minutes with both covers on.

c. If the instrument is not within specifications after the calibration, follow the troubleshooting procedures or contact Keithley Instruments, Inc., or its representative.

5-2. CALIBRATION SCHEDULE. Check the accuracy of the output voltage (paragraph 5-4) every six months and recalibrate as necessary. Also, recalibrate the instrument if either the series regulator tube, V101, or the zener diode, D116, is replaced.

5-3. ZERO BALANCE ADJUSTMENT.

a. This adjustment sets the Model 245 for no output when the Voltage Dials and Trim Control are set to 0 0 0 0.

b. Set the front panel controls to:

POWER ON Switch	on
OUTPUT ON Switch	on
Voltage Dials and Trim Control	0 0 0 0
POLARITY Switch	(-)

Connect the Model 153 to the Model 245 OUTPUT Receptacle and set it initially to its 10-millivolt range. Adjust the ZERO potentiometer, R125 (Figure 17), for zero output ±1 millivolt.

5-4. VOLTAGE CALIBRATION.

a. Connect the Model 662 to the Model 245 OUTPUT Receptacle. Allow the Voltage Supply to warm up for at least 30 minutes. Set the front panel controls to:

POWER ON Switch	on
OUTPUT ON Switch	on
Voltage Dials and Trim Control	any output above 100 volts
POLARITY Switch	(-)

b. The Model 662 should read the Model 245 output to ±0.5%. If necessary, adjust the output using the CAL potentiometer R139 (Figure 17). If the potentiometer does not have sufficient range, add or remove jumpers across resistor R136, R137 and R138 (See schematic diagram 21581E).

TABLE 8. Model 245 Internal Controls.

The Table lists all internal controls, the figure picturing the location and the paragraph describing the adjustment.

Control	Circuit Desig.	Fig. Ref.	Refer to Paragraph
Zero Adjustment	R125	17	5-3
Calibration Adjustment	R139	17	5-4
Current Limit Adjustment	R130	17	5-5

c. For a quick check, measure the output voltage at several different settings. Adjust the CAL potentiometer R139 (Figure 17) for minimum percentage deviation from the dial setting.

d. For best accuracy, check each ranging resistor and then adjust the CAL potentiometer for minimum deviation from the dial setting. Check the resistor by measuring the output voltage at each dial setting for each Voltage Dial. Keep two Dials set to zero and measure the output for each position of the third dial. Output should be within ±0.5% of the setting.

5-5. CURRENT LIMIT CIRCUIT ADJUSTMENT.

a. This adjustment sets the Model 245 current limit circuit for maximum current output. The factory adjustment is for a short circuit current of 12.5 milliamperes, although the adjustment range is from 7 to 17 milliamperes. This range provides a useful output current from about 5 to 15 milliamperes. At outputs above 10 milliamperes, however, some specifications may be degraded. (See paragraph 2-5.)

b. Connect the Model 153 to the Model 245 OUTPUT Receptacle. (If an equivalent ammeter is used, its input drop must be less than 150 millivolts.) Initially, set the Model 153 sensitivity to 30 milliamperes full scale. Set the Model 245 controls to

POWER ON Switch	on
OUTPUT ON Switch	on
Voltage Dials and Trim Control	0 1 0 0
POLARITY Switch	(-)

Adjust the CURRENT LIMIT potentiometer R130 (Figure 17) until the output current is 12.5 milliamperes ±0.2 milliampere.

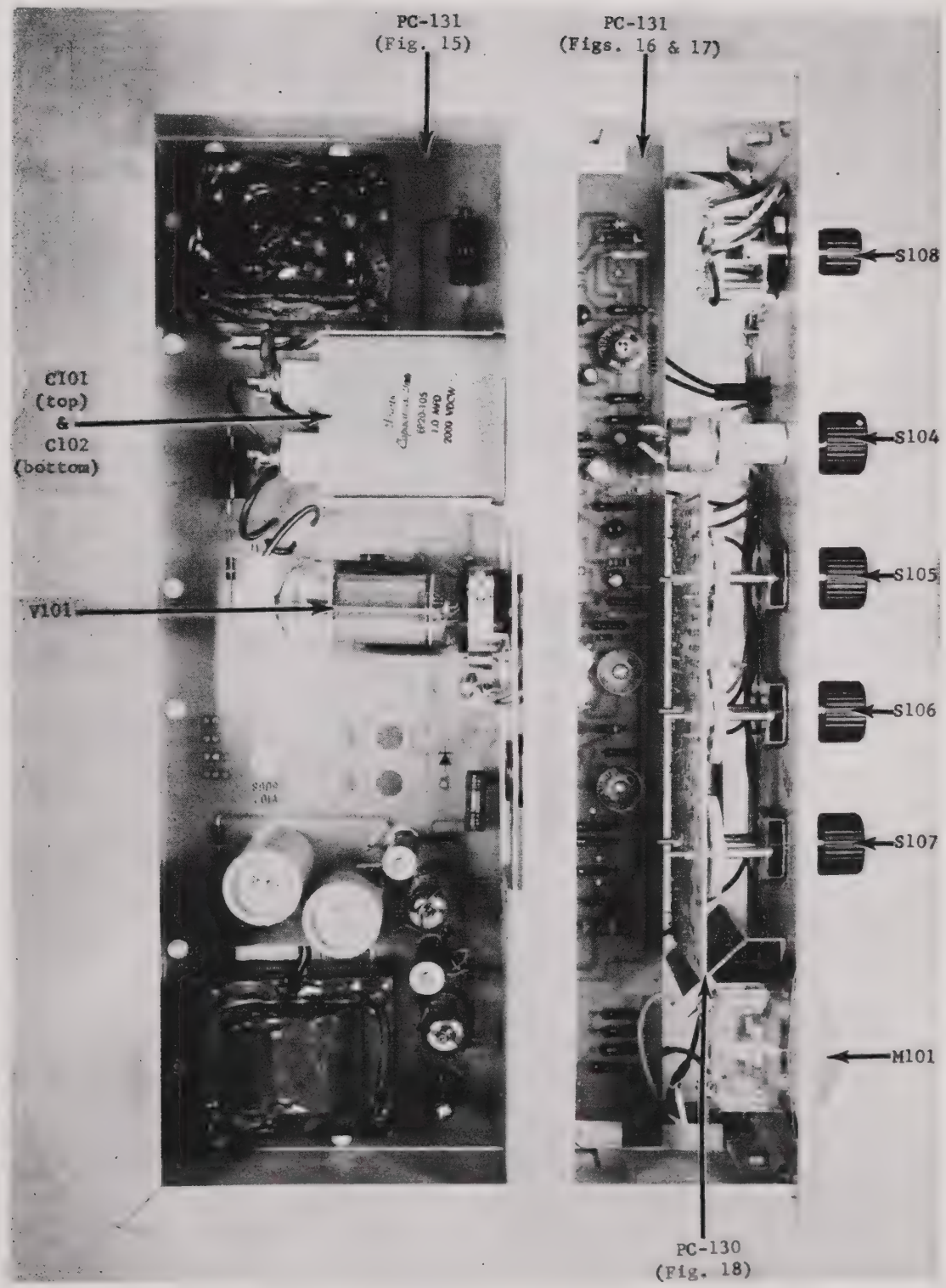


FIGURE 13. Top View of Model 245 Chassis. Front panel faces right. Figure shows components, switches and printed circuit board locations. Refer to Figure 14 for bottom view.

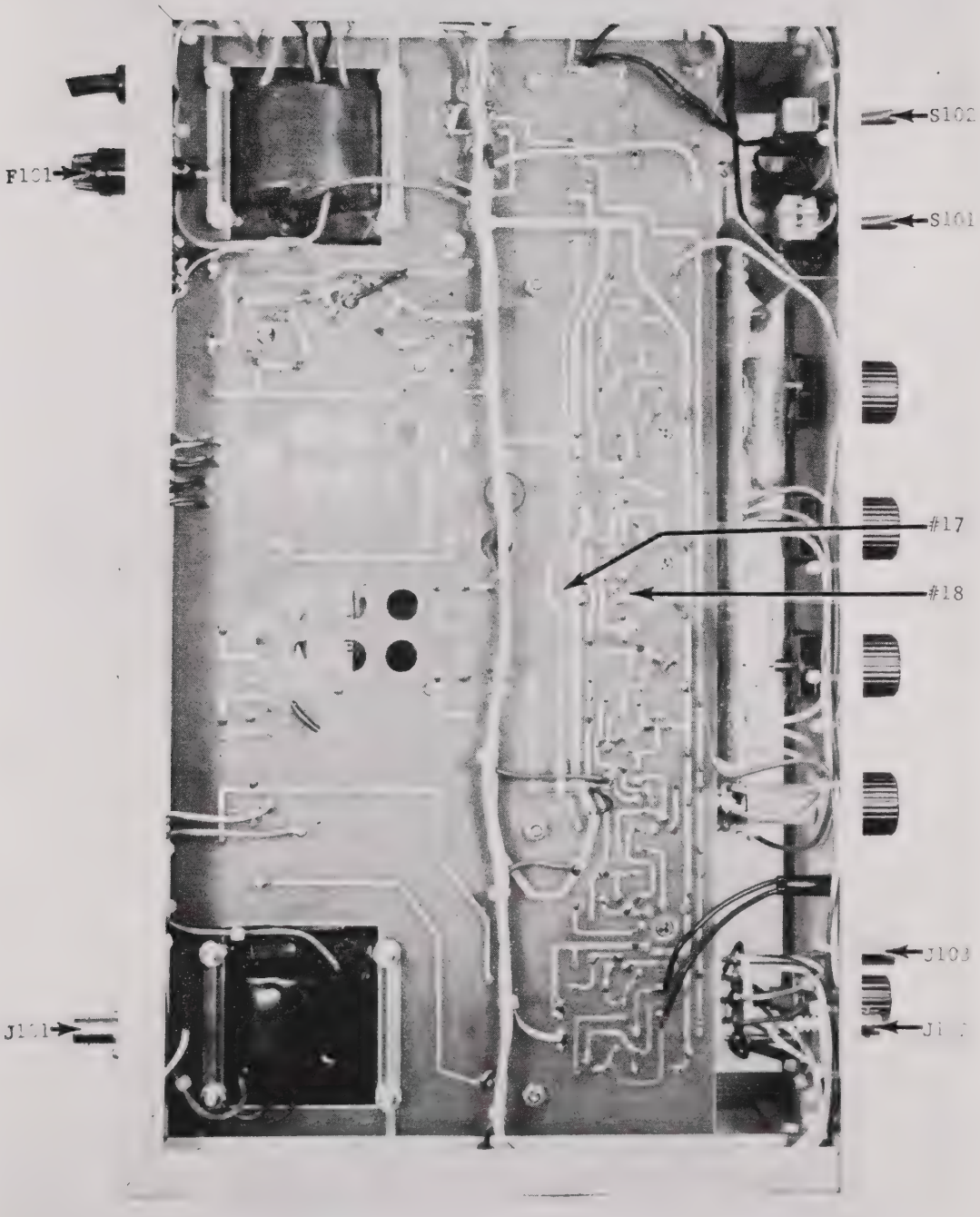


FIGURE 14. Bottom View of Model 245 Chassis. Front panel faces right. Figure shows locations of connectors, eyelets and switches. For top view refer to Figure 13.

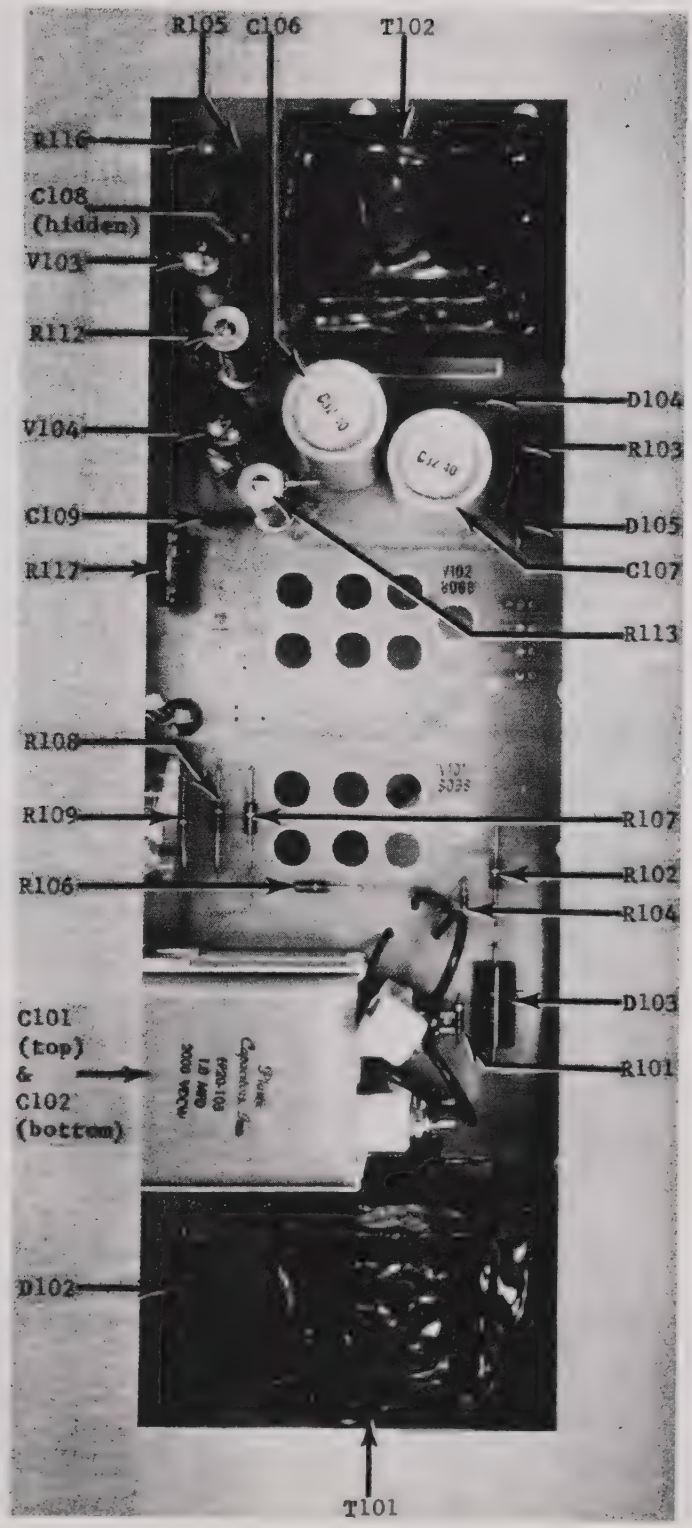


FIGURE 15. Component Locations on Rear Section. of PC-131. For other components see Figures 16 and 17.

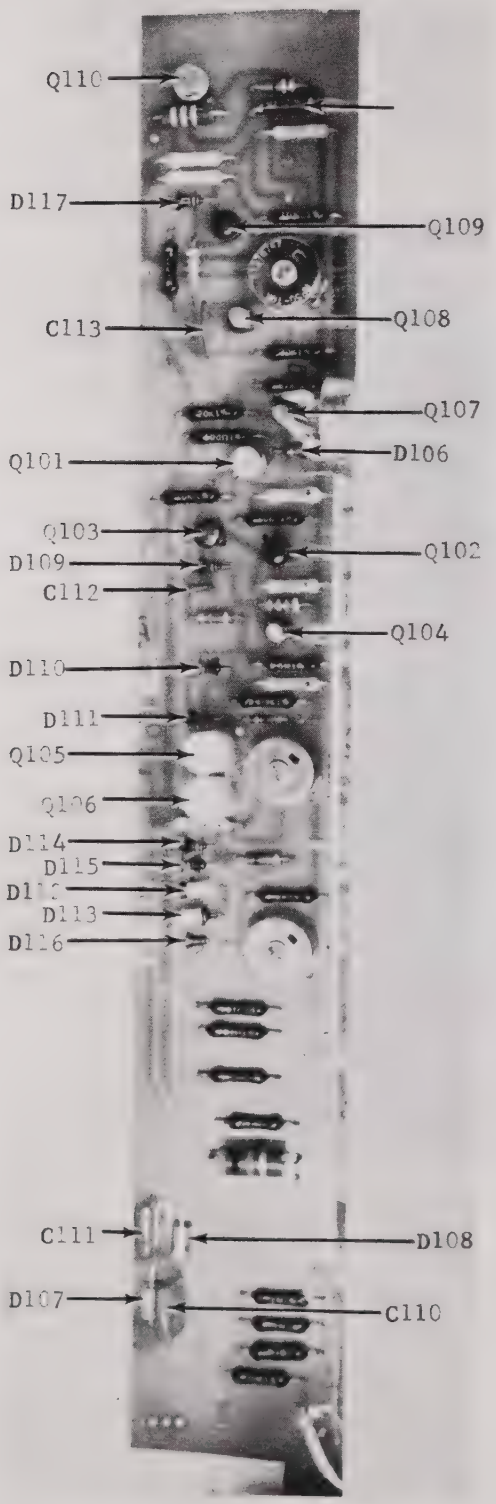


FIGURE 16. Capacitor, Diode and Transistor Locations on Front Section of PC-131.

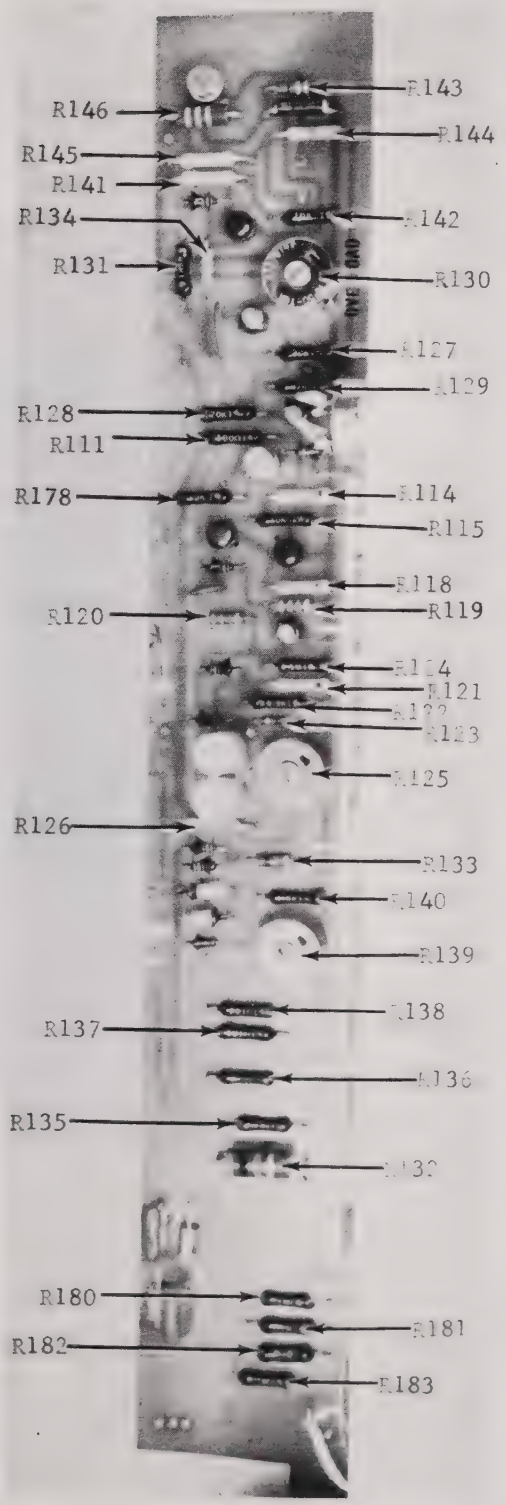


FIGURE 17. Resistor Locations on Front Section of PC-131.

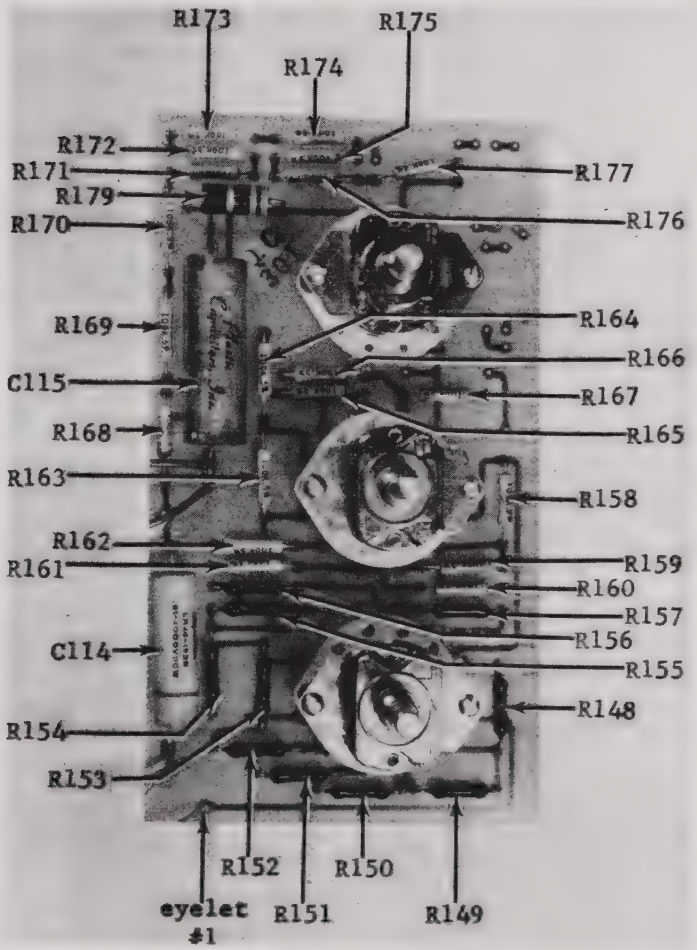


FIGURE 18. Component and Eyelet Locations on PC-130.

SECTION 6. ACCESSORIES

6-1. RACK MOUNTING.

a. Adding Rack Angles. The Model 245 is supplied with all the necessary hardware for standard RETMA 19-inch rack mounting. The rack angles are packed separately to fascilitate shipping.

1. Remove the four 10-32 slotted head screws on the sides of the instrument.

2. Place the angles against the instrument sides so that the mounting holes line up. Insert the screws.

6-2. MODEL 3008 BENCH MOUNTING KIT (See Figure 19.).

a. If bench mounting of the Model 245 is desired, use the Model 3008 Bench Mounting Kit. Assemble as follows:

1. Remove the four 10-32 slotted head screws that secure the rack angles and, if attached, the rack angles. Remove the top cover assembly by turning the two pawl-type fasteners one-half turn counter-clockwise. Remove the bottom cover assembly the same way.

2. Attach the bail supports (items 3 & 4) to the bottom cover, using two 8-32 x 7/16 Phillips Pan Head screws (item 8).

3. Attach the four feet (item 5), using four 8-32 x 7/16 screws (item 6). Snap the bail (item 9) into place. Push a rubber foot insert (item 7) into each plastic foot.

4. Replace the bottom cover assembly on the instrument and secure in place with the two pawl-type fasteners.

5. Place the bench top cover assembly (item 1) over the instrument. Use the four slotted head screws (item 2) to secure the cover to the instrument at the bottom corners of each side.

TABLE 9.

Model 3008 Bench Mounting Kit Parts List.

Item (See Figure 19)	Description	Keithley Part No.	Quantity
1	Cover Assembly with handles	20508B	1
2	Screw, Slotted Binder Head, 10-32 x 1/4	---	4
3	Bail Support, Right	19206B	1
4	Bail Support, Left	19205B	1
5	Plastic Foot	FE-5	4
6	Screw, Phillips Round Head, 8-32 x 7/16	---	4
7	Rubber Foot Insert	FE-6	4
8	Screw, Phillips Pan Head, 6-32 x 3/16	---	2
9	Tilt Bail	14704B	1

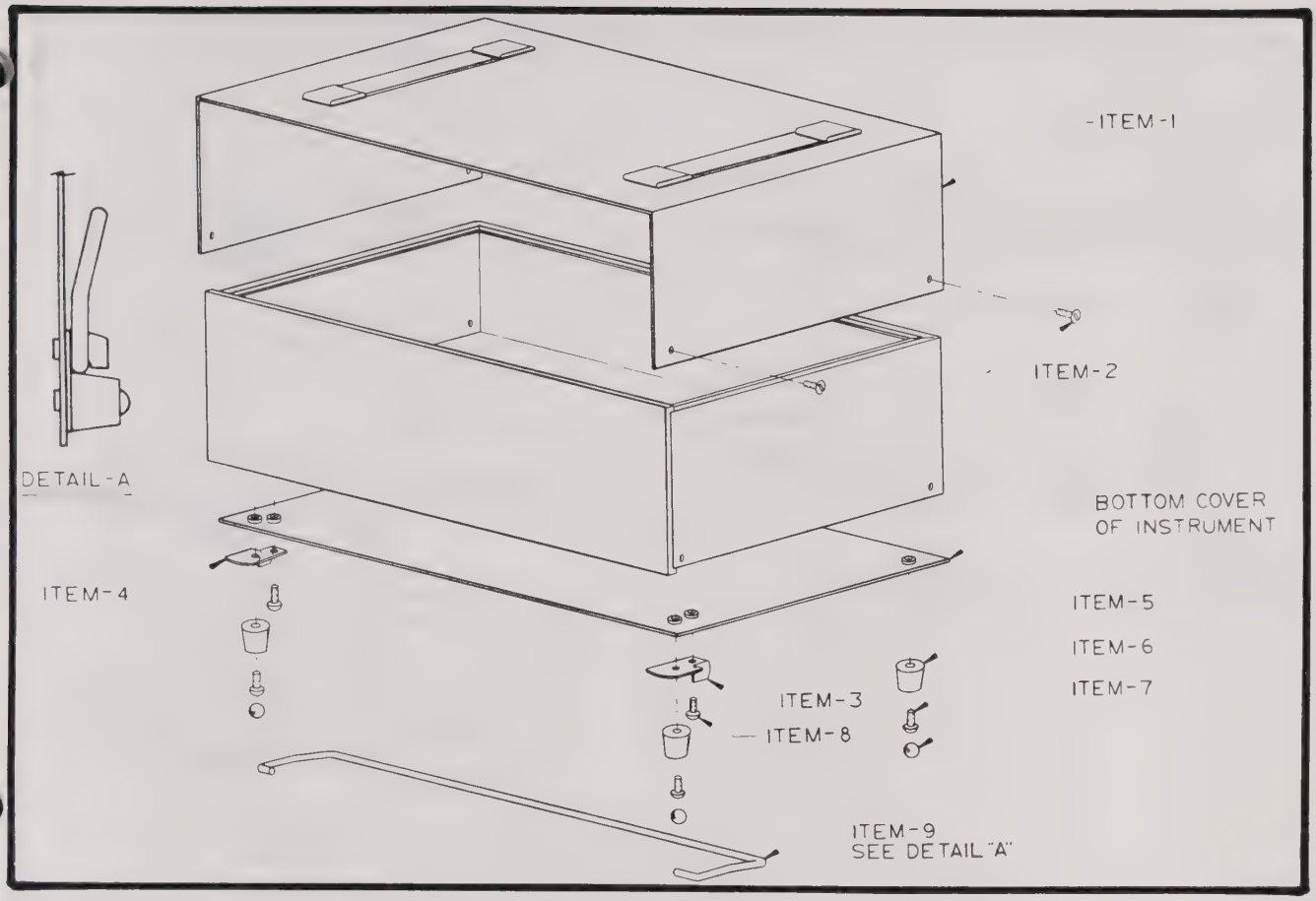


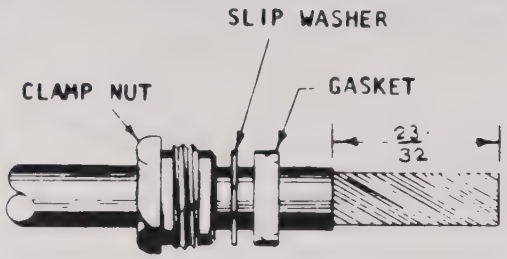
FIGURE 19. Exploded View for Assembling Model 3008 Bench Mounting Kit to Model 245.

6-3. MHV MATING CONNECTOR CABLE ASSEMBLAGE.

a. Shipped with the Model 245 is a mating MHV connector. This connector has the Military Type Number of UG-932/U, Keithley Part Number CS-191. It may be obtained from almost any manufacturer of connectors.

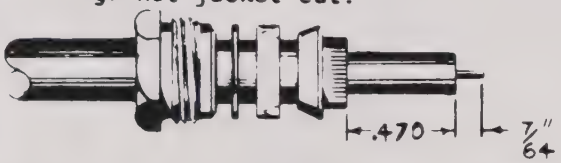
b. Keithley does not supply the connector already assembled with a cable. Therefore, it is necessary for the user to assemble the cable to the mating connector. Use coaxial cable that is capable of withstanding the maximum applied voltage.

c. Assembel the cable as shown in Figure 20.



1. Cut cable end square place clamp nut, slip washer and gasket over jacket. Strip jacket 23/32" as shown.

2. Comb out braid and taper forward. Then place braid clamp over braid against jacket cut.



3. Fold braid back over braid clamp and trim as shown. Cut dielectric and center conductor to 7/64" dimension then strip dielectric to .470 dimension.

4. Solder contact to center conductor.

5. Slide back end parts forward then thread assembly into connector and lock securely. Vee gasket must be split by braid clamp.

FIGURE 20. Cable Assembly for Mating MHV Connector.

SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 245 and its accessories. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column indicates the figure picturing the part. The name and address of the manufacturers listed in the "Mfg. Code" column are in Table 11.

7-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered through Keithley Instruments, Inc., or its representatives. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley representative or the Sales Service Department, Keithley Instruments, Inc.

TABLE 10. Abbreviations and Symbols.

A	ampere	M or meg	mega (10^6) or megohms
		Mil. No.	Military Type Number
Cb Var	Carbon Variable	Mfg.	Manufacturer
CerD	Ceramic, disc	MtF	Metal Film
Comp	Composition	My	Mylar
DCb	Deposited Carbon	Ω	ohm
EMT	Electrolytic, metal cased	p	pico (10^{-12})
ETB	Electrolytic, tubular		
		Ref.	Reference
F	farad		
Fig.	Figure	μ	micro (10^{-6})
HTC	Hot Tinned Container	V	volt
k	kilo (10^3)	W	watt
		WW	Wirewound

MODEL 245 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 21581E for circuit designations)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	1 μF	2000 V	HTC	99120	EP20-105	C166-1M	13, 15
C102	1 μF	2000 V	HTC	99120	EP20-105	C166-1M	13, 15
C103	Not used.						
C104	Not used.						
C105	2 μF	25 V	Plastic	56289	TL1201	C159-2M	
C106	40 μF	350 V	EMC	14659	TVL 1621	C32-40M	15
C107	40 μF	350 V	EMC	14659	TVL 1621	C32-40M	15
C108	.02 μF	600 V	CerD	72982	Ed-.02	C22-.02M	15
C109	.02 μF	600 V	CerD	72982	Ed-.02	C22-.02M	15
C110	.22 μF	50 V	My	84411	601 PE	C41-.22M	16
C111	0.1 μF	50 V	My	84411	601 PE	C41-.1M	16
C112	*100 pF	600 V	CerD	72982	Ed-100	C22-100P	16
C113	.02 μF	600 V	CerD	72982	Ed-.02	C22-.02M	16
C114	.01 μF	4000 V		99120	LR40-103B	C156-.01M	18
C115	.05 μF	4000 V		99120	LR40-503	C157-.05M	18

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Not used.				
D102	Silicon	7715-8	02101	RF-32	15
D103	Silicon	7715-8	02101	RF-32	15
D104	Silicon	1N3256	02735	RF-22	15
D105	Silicon	1N3256	02735	RF-22	15
D106	Silicon	1N645	01295	RF-14	16
D107	Zener	ZV20	15238	DZ-25	16
D108	Zener	ZV20	15238	DZ-25	16
D109	Silicon	1N645	01295	RF-14	16
D110	Silicon	1N645	01295	RF-14	16
D111	Silicon	1N645	01295	RF-14	16
D112	Silicon	1N645	01295	RF-14	16
D113	Silicon	1N645	01295	RF-14	16
D114	Silicon	1N3253	80164	17459A	16
D115	Silicon	1N3253	80164	17459A	16
D116	Zener	1N936	04713	DZ-5	16
D117	Silicon	1N645	01295	RF-14	16

* Nominal value, factory set.

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
DS101	Pilot Light, Red, OUTPUT ON (Mfg. No. 2100)	91802	PL-38	2
DS102	Pilot Light, White, POWER ON (Mfg. No. 2100)	91802	PL-34	2
DS103	Pilot Light, Red, (Mfg. No. 2100)	91802	PL-35	2
DS104	Neon Light (Mfg. No. NE-83)	08811	PL-41	
F101 (117v)	Fuse, slow blow, 3AG, 1.25 A	80164	FU-28	14
F101 (234v)	Fuse, slow blow, 3AG, .625 A	80164	FU-27	
---	Fuse Holder (Mfg. No. 342012)	75915	FH-3	
J101	Receptacle, output (Mil. No. UG-931/U)	02660	CS-190	14
---	Plug, mate of J101 (Mil. No. UG-932A/U)	02660	CS-191	
---	Sleeve cap for J102	99017	CAP-19	
J102	Receptacle, output (Mil. No. UG-931/U)	02660	CS-190	2,14
---	Plug, mate of J102 (Mil. No. UG-932A/U)	02660	CS-191	
---	Sleeve cap for J102	99017	CAP-19	
J103	Binding Post (Mfg. No. 33-286)	08811	BP-15	2,14
M101	Meter	80164	ME-80	2,13
P101	Cord Set, 6 feet (Mfg. No. 4638-13)	93656	CO-5	
S101	Toggle Switch, OUTPUT ON	80164	SW-238	2,14
S102	Toggle Switch, POWER ON	80164	SW-4	2,14
S103	Slide Switch, 117-234 V	80164	SW-151	
S104	Trim Control potentiometer	80164	RP56-16.5K	2,13
---	Dial Assembly, Trim Control	80164	20932A	
S105	Rotary Switch, X10 Output Volts	80164	SW-211	2,13
---	Dial Assembly, X10 (0-10)	80164	14829A	
S106	Rotary Switch, X100 Output Volts	80164	SW-211	2,13
---	Dial Assembly, X100 (0-10)	80164	14829A	
S107	Rotary Switch, X1000 Output Volts	80164	SW-242	2,13
---	Dial Assembly, X1000 (0-1)	80164	21573A	
S108	Rotary Switch, POLARITY	80164	SW-230	2,13
---	Knob Assembly, Polarity Switch	80164	14838A	
T101	Transformer	80164	TR-106	15
T102	Transformer	80164	TR-105	15

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	100 Ω	10%, 1/2 W	Comp	01121	EB	R1-100	15
R102	5.6 MΩ	10%, 1/2 W	Comp	01121	EB	R1-5.6M	15
R103	47 Ω	5%, 3 W	WW	44655	4400	R92-47	15
R104	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	15
R105	33 kΩ	10%, 1/2 W	Comp	01121	EB	R1-33K	15
R106	5.6 MΩ	10%, 1/2 W	Comp	01121	EB	R1-5.6M	15
R107	5.6 MΩ	10%, 1/2 W	Comp	01121	EB	R1-5.6M	15
R108	5.6 MΩ	10%, 1/2 W	Comp	01121	EB	R1-5.6M	15
R109	5.6 MΩ	10%, 1/2 W	Comp	01121	EB	R1-5.6M	15
R110	Not used.						
R111	100 Ω	1%, 1/2 W	MtF	07716	CEC	R94-100	17
R112	1.75 kΩ	±5%, 20 W	WW	05766	FR-20	R141-1.75K	15
R113	3 kΩ	±5%, 20 W	WW	05766	FR-20	R141-3K	15
R114	30.1 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-30.1K	17
R115	10 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-10K	17
R116	4.5 kΩ	5%, 10 W	WW	44655	1-3/4-D-57-F	R5-4.5K	15
R117	9 kΩ	10%, 5 W	WW	05766	FRL-5	R131-9K	15
R118	3.48 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-3.48K	17
R119	47 kΩ	10%, 1/2 W	Comp	01121	EB	R1-47K	17
R120	*6.8 kΩ	10%, 1/2 W	Comp	01121	EB	R1-6.8K	17
R121	121 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-121K	17
R122	33.3 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-33.3K	17
R123	100 Ω	10%, 1/4 W	Comp	01121	CB	R76-100	17
R124	1.5 MΩ	1%, 1/2 W	MtF	07716	CEC	R94-1.5M	17
R125	2 kΩ	20%, 2 W	WW	71450	1NS 115	RP50-2K	17
R126	909 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-909K	17
R127	20 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-20K	17
R128	20 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-20K	17
R129	187 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-187K	17
R130	10 kΩ	20%, 2 W	WW	71450	1NS 115	RP50-10K	17
R131	8.06 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-8.06K	17
R132	100 Ω	10%, 2 W	Comp	01121	HB	R3-100	17
R133	1 kΩ	10%, 1/2 W	Comp	01121	EB	R1-1K	17
R134	47 kΩ	10%, 1/2 W	Comp	01121	EB	R1-47K	17
R135	8.25 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-8.25K	17
R136	301 Ω	1%, 1/2 W	MtF	07716	CEC	R94-301	17
R137	301 Ω	1%, 1/2 W	MtF	07716	CEC	R94-301	17
R138	301 Ω	1%, 1/2 W	MtF	07716	CEC	R94-301	17
R139	500 Ω	20%, 2 W	WW	71450	1NS 115	RP50-500	17
R140	*1.3 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-1.3K	17

* Nominal value, factory set.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R141	10 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-10K	17
R142	2.74 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-2.74K	17
R143	100 kΩ	10%, 1/2 W	Comp	01121	EB	R1-100K	17
R144	23.2 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-23.2K	17
R145	1.21 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-1.21K	17
R146	56 kΩ	10%, 1 W	Comp	01121	GB	R2-56K	17
R147	16.5 kΩ	±10%	CbVar	71590	Model 2	RP56-16.5K	2
R148	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R149	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R150	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R151	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R152	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R153	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R154	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R155	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R156	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R157	10 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-10K	18
R158	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R159	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R160	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R161	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R162	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R163	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R164	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R165	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R166	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R167	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R168	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R169	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R170	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R171	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R172	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R173	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R174	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R175	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R176	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R177	100 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-100K	18
R178	10 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-10K	17
R179	33 Ω	10%, 2 W	Comp	01121	HB	R3-33	18
R180	1 MΩ	1%, 1/2 W	MtF	07716	CEC	R94-1M	17

RESISTORS (Cont'd.)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R181	1 MΩ	1%, 1/2 W	MtF	07716	CEC	R94-1M	17
R182	1 MΩ	1%, 1/2 W	MtF	07716	CEC	R94-1M	17
R183	1 MΩ	1%, 1/2 W	MtF	07716	CEC	R94-1M	17

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101*	40346	80164	21676A	16
Q102*	S17638	80164	21675A	16
Q103*	S17638	07263	21675A	16
Q104	A1380	73445	TG-32	16
Q105**	A1380	80164	19447A	16
Q106**	A1380	80164	19447A	16
Q107	A1380	73445	TG-32	16
Q108	A1380	73445	TG-32	16
Q109	S17638	07263	TG-33	16
Q110	40346	02735	TG-44	16

VACUUM TUBES

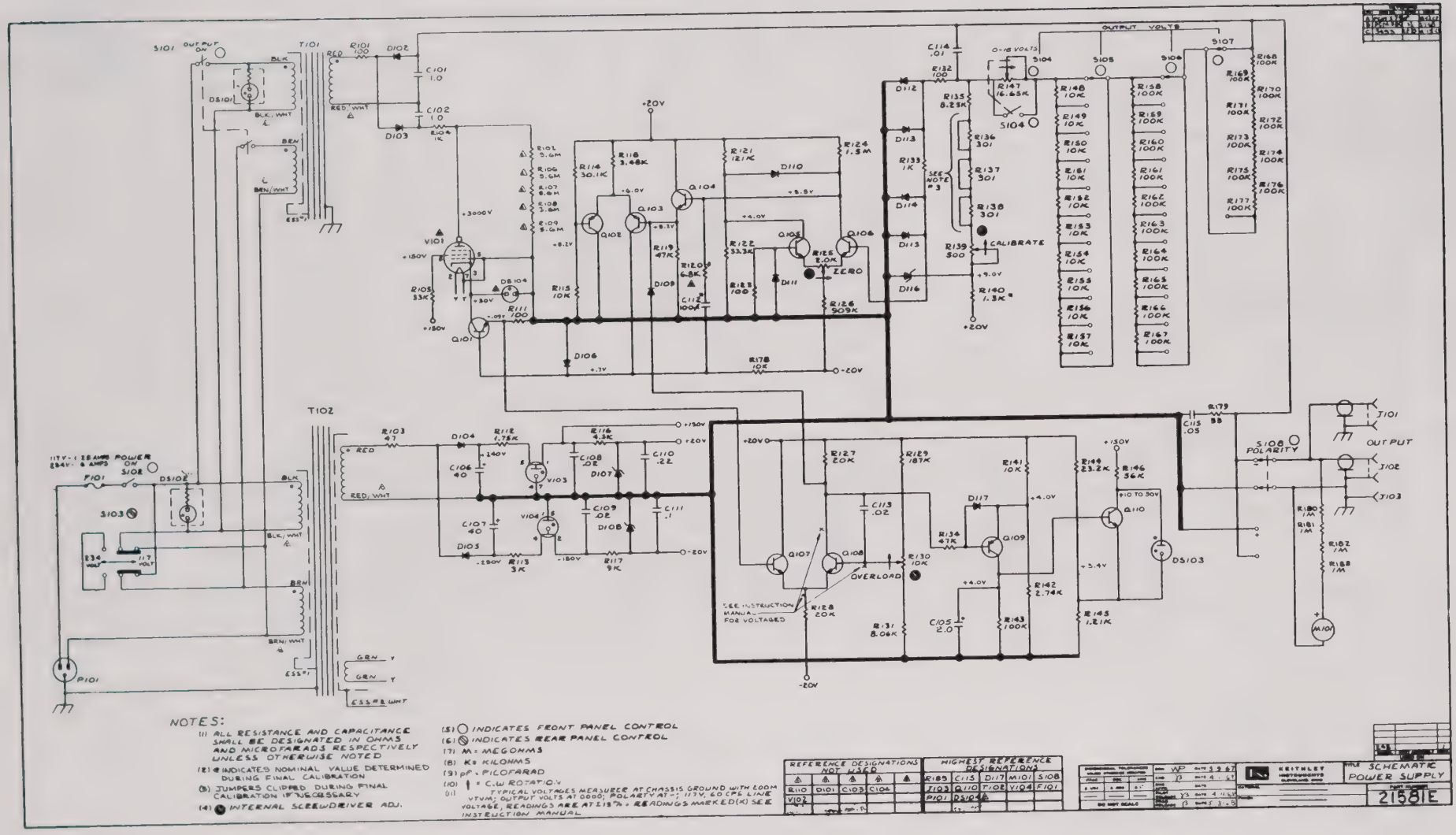
Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V101	8068	03507	EV-8068	13
V103	OA2	86684	EV-OA2	15
V104	OA2	86684	EV-OA2	15

* Q101, Q102 and Q103 are selected transistors, order only from Keithley Instruments, Inc.
** Q105 and Q106 are matched transistors, order only as a pair from Keithley Instruments, Inc.

TABLE 11.

Code List of Suggested Manufacturers. Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.

01121	Allen-Bradley Corp. Milwaukee, Wis.
01295	Texas Instruments, Inc. Semiconductor-Components Division Dallas, Texas
02101	Varo, Inc., Electrokinetics Div. Santa Barbara, Calif.
02660	Amphenol Corp. Broadview, Ill.
02735	Radio Corp. of America Commercial Receiving Tube and Semiconductor Division Sommerville, N.J.
03507	G.E. Power Tube Department Schenectady, New York
04713	Motorola, Inc. Semiconductor Product Division Phoenix, Arizona
05766	Tru-Seal Div. of Flick-Reedy Corp. Melrose Park, Ill.
07263	Fairchild Camera and Instrument Corp. Semiconductor Division Mountain View, Calif.
07716	International Resistance Co. Burlington, Iowa
08811	G-L Electronics Co., Inc. Camden, New Jersey
14659	Sprague Electric Co. Visalia, Calif.
15238	ITT Components Selenium Dept. Mfg. Div. of ITT Semiconductor Inc. Lawrence, Mass.
44655	Ohmite Mfg. Co. Skokie, Ill.
56289	Sprague Electric Co. North Adams, Mass.
71450	CTS Corp. Elkhart, Ind.
71590	Centralab Division of Globe-Union Inc. Milwaukee, Wis.
72982	Erie Technological Products, Inc. Erie, Pa.
73445	Amperex Electronic Co. Div. of North American Philips Co. Inc. Hicksville, N.Y.
75915	Littlefuse, Inc. Des Plaines, Ill.
80164	Keithley Instruments, Inc. Cleveland, Ohio
84411	TRW Capacitor Division Ogallala, Nebr.
86684	Radio Corp. of America Electronic Components and Devices Harrison, N.J.
91637	Dale Electronics Inc. Columbus, Nebr.
91802	Industrial Devices Inc. Edgewater, N.J.
93656	Electric Cord Co. Caldwell, N.J.
99017	Protective Closures Co., Inc. C.A. Plugs Division Buffalo, N.Y.
99120	Plastic Capacitors Inc. Chicago, Ill.



NOTES:

(1) ALL RESISTANCE AND CAPACITANCE SHALL BE DESIGNATED IN OHMS AND MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED

(2) ⊕ INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION

(3) JUMPERS CLIPPED DURING FINAL CALIBRATION IF UNNECESSARY

(4) ⊕ INTERNAL SCREWDRIVER ADJ.

(5) ◯ INDICATES FRONT PANEL CONTROL

(6) ⊘ INDICATES REAR PANEL CONTROL

(7) M = MEGOHMS

(8) K = KILOHMS

(9) pF = PICOFARAD

(10) ↻ = C.W ROTATION

(11) TYPICAL VOLTAGES MEASURED AT CHASSIS GROUND WITH ZOOM VTVM; OUTPUT VOLTS AT 0000; POLARITY AT -; 117V, 60 CPS LINE VOLTAGE, READINGS ARE AT ±15%. READINGS MARKED (X) SEE INSTRUCTION MANUAL

REFERENCE DESIGNATIONS NOT USED				
R110	D101	C103	C104	
V102				

HIGHEST REFERENCE DESIGNATIONS				
R183	C115	D117	M101	S108
J103	Q110	T102	V104	F101
P101	DS103			

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC POWER SUPPLY

PART NUMBER 21581E

U.S.A. and Canada sales offices

1■ KEITHLEY INSTRUMENTS, INC.
28775 Aurora Road
Cleveland, Ohio 44139
(216) 248-0400

2 KEITHLEY INSTRUMENTS, INC.
5817 Baltimore Boulevard
Riverdale, Maryland 20840
(301) 277-5111

3 KEITHLEY INSTRUMENTS, INC.
101 East Lancaster Avenue
Wayne, Pennsylvania 19087
(215) 687-1170

4 KEITHLEY INSTRUMENTS, INC.
12-94 Plaza Road
Fair Lawn, New Jersey 07410
(201) 797-5440

5 KEITHLEY INSTRUMENTS, INC.
235 Bear Hill Road
Waltham, Massachusetts 02154
(617) 891-4428

6 KEITHLEY INSTRUMENTS, INC.
Pickard Building, Room 140
5858 East Molloy Road
Syracuse, New York 13211
(315) 455-6696

7 KEITHLEY INSTRUMENTS, INC.
6300 North Cicero Avenue
Chicago, Illinois 60646
(312) 545-3690

8 MURPHY & COTA
1106 Burke Street
Winston-Salem,
North Carolina 27101
(919) 724-0750

904 Bob Wallace Avenue
Huntsville, Alabama 35801
(205) 539-8476

712 West Vassar Street
Orlando, Florida 32804
(305) 424-2407

9 JOHN A. GREEN CO.
7118 Envoy Court
Dallas, Texas 75247
(214) 631-7450

3400 Montrose Boulevard
Houston, Texas 77006
(713) 526-2959

P. O. Box 3209
Tulsa, Oklahoma 74101
(918) 742-4657

10 AZTEC ENTERPRISES, INC.
3202 Candelaria Road, N. E.
Albuquerque, New Mexico 87107
(505) 345-3441

3385 S. Bannock
Englewood, Colorado 80110
(303) 761-0101

Salt Lake City, Utah
Zenith 957

11 KEITHLEY INSTRUMENTS, INC.
825 San Antonio Road
Palo Alto, California 94303
(415) 321-5291

12■ KEITHLEY INSTRUMENTS, INC.
15010 Ventura Boulevard
Sherman Oaks, California 91403
(213) 784-1159

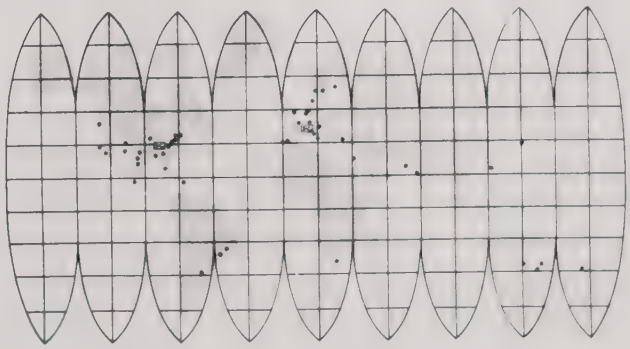
13 AURORA TECHNICAL INDUSTRIES, LTD.
#2-650 Clyde Avenue
West Vancouver, British Columbia
(604) 922-0136

14 NO REPRESENTATIVE
(See 1)

■ Authorized Service Center

european services

Keithley has a manufacturing facility in Germany and a warehouse and office in Switzerland to provide prompt delivery in the European area. The facilities, staffed by Keithley field engineering personnel, give on-the-spot assistance to your Keithley representative so that he may better serve you. A list of the worldwide Keithley representatives is given on the back.



KEITHLEY INSTRUMENTS, INC.
28775 AURORA ROAD • CLEVELAND, OHIO 44139
TELEPHONE: (216) 248-0400
TELEX: 98-5469

LITHO IN U.S.A.
368

REPAIR AND CALIBRATION FORM

For repair or calibration, please fill out this form and return it with your instrument to:

Sales Service Department
Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

R-_____
Do not write in this space.

User's Name _____ Telephone _____ Ext. _____
Company _____ Address _____
Division _____ City _____ State _____ Zip _____
Date _____ Model No. _____ Serial No. _____

1. Reason for Return
   - ☐ Repair and Recalibration
   - ☐ Recalibration only (No report, except as specified in item 4 on reverse)*

   *If repairs are necessary to meet specifications, they will be in addition to the calibration.

2. Calibration Report Desired
   - ☐ Report of Calibration Certified Traceable to N.B.S.
   - ☐ Calibration Report
   - ☐ Certificate of Compliance
   - ☐ None

   (for details, see reverse side of this form)

3. To help repair the instrument, briefly describe the problem: _____

4. Is the problem ☐ Constant ☐ Intermittant
   Under what conditions does the problem occur:
   a) Control setting _____
   b) Approx. Temperature _____ °F
   c) Approx. Temperature variation ± _____ °F
   d) Approx. Humidity (high, medium, low) _____
   e) Line voltage _____
   f) Other (such as line transients, line variations, etc.) _____

5. Please draw a block diagram of the system using the Keithley. List any other pertinent data which can help in the repair. Include charts or other data if available.
   Signal Source _____
   Source Impedance _____
   Readout Device:
   - ☐ Recorder
   - ☐ Oscilloscope
   - ☐ Other
   - ☐ None

   Lengths & Types of Connecting Cables _____

6. What repairs or modifications have been made on this instrument which are not on file with the Keithley Repair Department? _____

7. Please enclose any other pertinent data and charts which you feel might help the Repair and Calibration Department

_____ Signature _____ Title

CALIBRATIONS AVAILABLE AT KEITHLEY INSTRUMENTS.

Listed and defined below are the four types of calibrations and their associated report formats which are presently available at Keithley Instruments. They fall into the following categories:

1. Report of Calibration Certified Traceable to the National Bureau of Standards
2. Calibration Report
3. Certificate of Compliance
4. Recalibration

All calibration and certification performed by Keithley Instruments is in accord with MIL-C-45662A.

Prices shown below are in addition to repair charges for any work necessary to place a customer's unit into first class condition prior to the calibration.

1. Report of Calibration Certified Traceable to the National Bureau of Standards.

This is a completely documented report, including all basic errors or deviations from nominal settings on appropriate ranges, terminals, dials, etc. Work is performed using the primary standards of the company with secondary transfers kept to a minimum. The NBS test numbers for the latest recalibration of the primary standards are furnished.

By definition, the above is performed in our Standards Laboratory so that random operator induced error is minimized and maximum protection to the equipment used is maintained.

This type of calibration is not recommended for instruments with a basic inaccuracy of 1% or greater. The precision involved in this report makes it uneconomical for such instruments. The Calibration Report listed below (No. 2) would be better suited in this case.

As of 12/1/67 the Report of Calibration Certified Traceable to the National Bureau of Standards is available on the following instruments at the prices listed:

Model 140	$325	Model 5155 (Complete Set)	$265
Model 260	$220	Model 5155-10^8	$ 45
Model 261	$280	Model 5155-10^9	$ 45
Model 515	$520	Model 5155-10^{10}	$ 45
Model 630	$250	Model 5155-10^{11}	$ 55
Model 660A	$200	Model 5155-10^{12}	$ 55
Model 662	$250	Model 5155-10^{13}	$ 75

2. Calibration Report.

This report shows only the cardinal range, terminal, dial, etc. errors as determined by production calibration equipment and personnel. The production equipment is maintained traceable by transfer techniques against the primary standards maintained by the company. We attest to this fact and list basic deviations from nominal but the conditions of calibration are not as precisely controlled as the previous report nor are NBS test numbers supplied.

This report is available for any instrument in our line. As of December 1, 1967, only the following price has been established for this report:

Model 261 . . . . . $50

Prices for other units can be estimated upon request.

3. Certificate of Compliance.

This is merely a restatement of the basic guarantee that the instrument was calibrated on equipment that is maintained by our standards personnel against primary standards. No report is issued.

This Certificate of Compliance is available at no charge for any instrument with the exception of the Model 261.

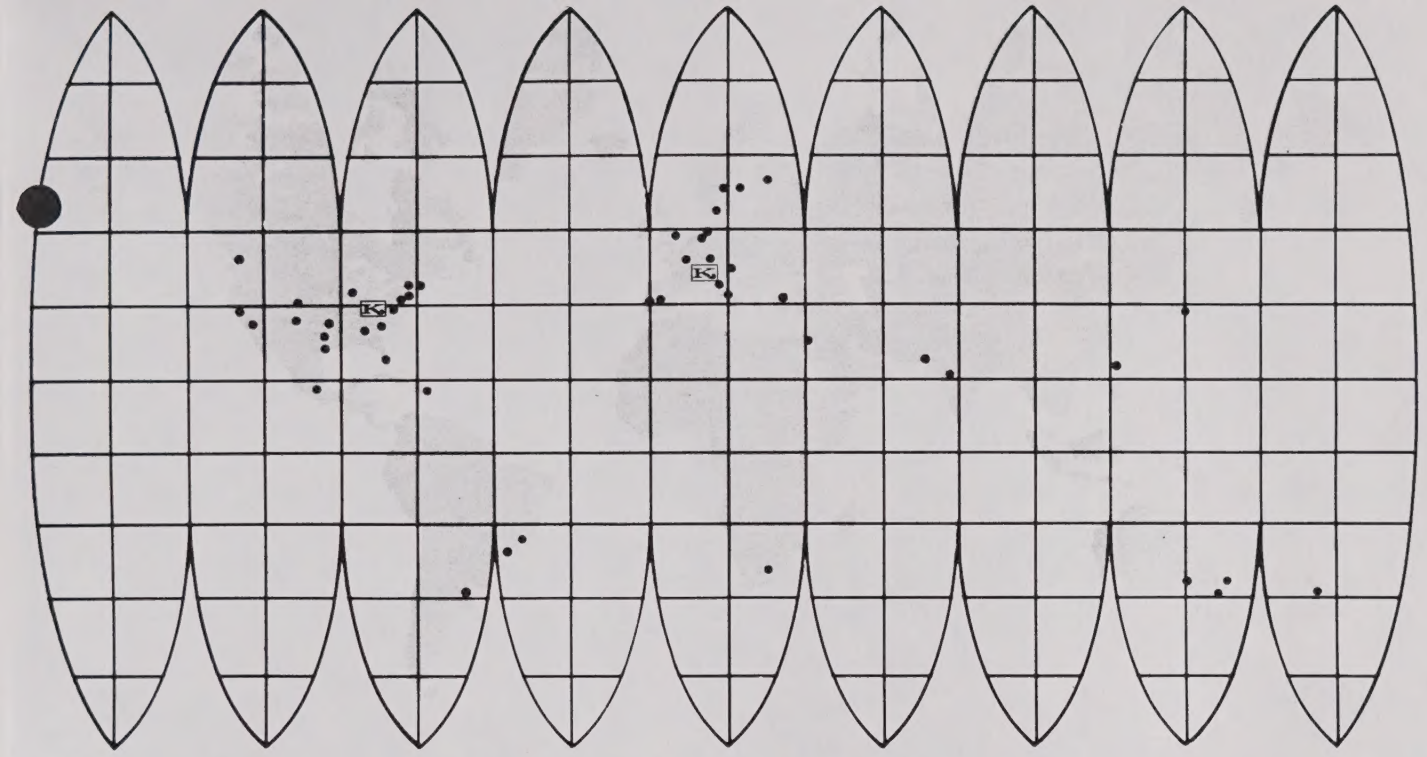
A newly purchased Model 261 or one returned for repair or recalibration is automatically supplied with a Calibration Report (as described in (2) above). The nature of this instrument makes it necessary to complete this report to ascertain specified accuracy. This Calibration Report is forwarded to the customer with the instrument. The $50 charge is incorporated as part of the normal calibration charge of the Model 261.

4. Recalibration.

This is a recalibration of the instrument according to our factory calibration procedures. The prices for this as of December 1, 1967 are as follows:

Model 260 . . . . . $75	(No report supplied. A Certificate of Compliance can be had at no charge if requested).
Model 261 . . . . . $50	(Calibration Report as described in (2) above is supplied. See (3) for explanation).

All other instruments are on a time and material basis for the particular unit involved.



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